1982
ANNUAL REVIEW OF ACTIVITIES

Institute
of
Ocean Sciences

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Institute of Ocean Sciences
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DEPARTMENT OF FISHERIES AND OCEANS

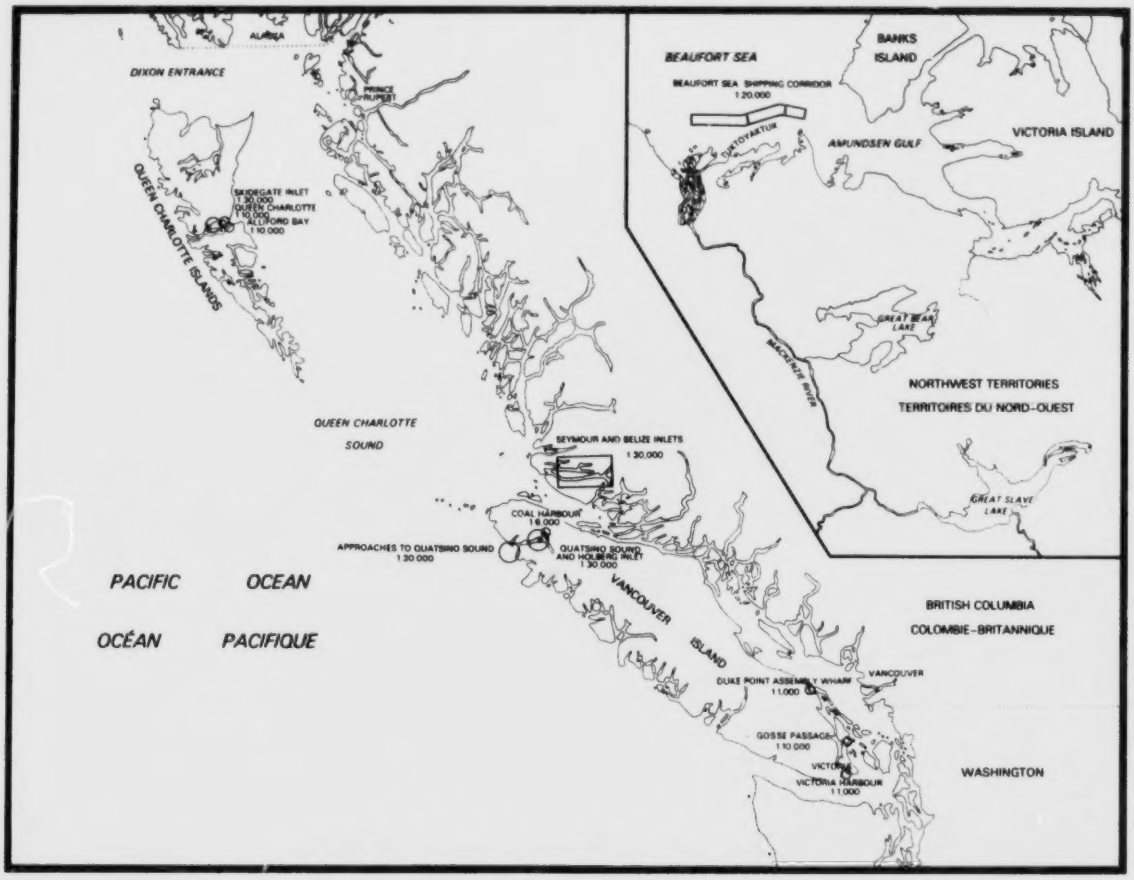
Director-General's Foreword

This year saw steady progress in hydrographic and oceanographic projects that had been initiated over the past few years. The work on charting a safe corridor for navigation through the Beaufort Sea, and on the assessment of the impact on the ocean environment of the molybdenum mine in Alice Arm, has gone very well. The charter vessel *Polar Circle* continued the survey of the Beaufort Sea corridor which is now 86% completed and should be finished next year. A major part of the field work for the Alice Arm project has been completed as planned. The field program will be finished in 1983 and a start made on the interpretation of the data. The Arctic continues to be an area of high priority to which we devote a considerable proportion of our resources. In addition to the hydrographic survey in the Beaufort Sea our Tides and Currents Section has expanded its tidal and current survey in the western Arctic and scientists in the Frozen Sea Research group are well into a major study of currents in the Canadian Arctic Archipelago as well as continuing their studies in the Arctic Ocean.

The programs in Ocean Information Services, Chemistry, and Ecology also acquired more substance this year due to past efforts. Ocean Information Services has published the first of a series of documents assessing and cataloguing all oceanographic data in the Arctic and west coast. One outcome of this effort has been that a great deal of data has been discovered that was not in the archives of the Marine Environment Data Service. We have also spent considerable effort reviewing EIS's and on advice regarding environmental problems. Chemistry and Ecology have made good use of the contracting process to expand their research. A large part of the benthic program is done by contract and in collaboration with the University of Victoria. Similarly much of the CO_2 and seaflux programs is accomplished by contract and in collaboration with scientists from other laboratories.

It is worth remarking that the use of acoustic transmission as a tool in oceanography has attracted oceanographers for many years. In the last few years interest in use of acoustic techniques has been renewed, experiments in acoustic tomography have been conducted by the United States over hundreds of kilometres of ocean which have proven successful. To work on this scale is beyond the means of IOS, however, we have several developmental, and novel, acoustic projects which add up to a very respectable program and which are described later in the report. It is our intention to continue with this effort in acoustics as it does promise to enable measurements which cannot readily be made by other means.

One of the difficulties in writing this foreword has been to pick out of our program items which merit special attention, a task that was really not possible this year. What follows is a description of some of the many areas in which progress has been made.



Pacific Region 1982 hydrographic survey program.

The Hydrographic Division continued to pursue its main objective which is the provision of current navigational information in the form of nautical charts, sailing directions and tidal and current tables. An extensive network of chart dealers is employed to disseminate these publications to the various commercial and recreational users.

Emphasis was placed, as in 1981, on continuing surveys of a navigational corridor through the Beaufort Sea, along with resurveys and revisory surveys of the Pacific Coast. A new small craft chart covering the mainland coast from Vancouver Harbour to Desolation Sound was published, and well received by the boating public. As well as conducting major current surveys in the Queen Charlotte Sound area, a long term circulation and mean sea level study was commenced in the western Arctic.

Two senior staff left during the year to join the private sector: J.V. Watt, Head of Engineering Services and A.D. O'Connor, Senior Field Hydrographer. Their enthusiasm and experience will be missed, however, this is perhaps, the most effective method of transferring technology from government to industry.

Ship Division continued to provide support to OSS Pacific programs, to other federal government departments and to Canadian west coast universities. In November, CSS *Parizeau* commenced her mid-life refit. Major modifications include engine and generator replacements plus additional enhanced accommodation for ships' personnel.

Field Hydrography

The Field Hydrography Section is responsible for conducting hydrographic surveys of the B.C. coast, western Arctic, and navigable inland waters of the Pacific Region in order to ensure that requirements for navigational information are met. Alterations of, and additions to, traffic routes, types and sizes of vessels, harbours, bottom topography and coastlines — all require an ongoing survey and resurvey program.

The major coastal survey party was assigned to the barge *Pender* from April to October. A survey of the previously uncharted Seymour, Belize and Nugent waterway complex was completed. At present this area is only covered by reconnaissance surveys made by the British Admiralty over one hundred years ago. The party completed their season with a resurvey of Holberg and Rupert Inlets and portions of Quatsino and Neroutsos Inlet to modern standards. *(Contact: G.E. Richardson.)*

CSS *Richardson* provided logistical support to a second coastal party which completed the ongoing resurvey of Skidegate Inlet in the Queen Charlotte Islands.

Later in the season this ship and party commenced surveys of portions of the approaches to Quatsino Inlet which were required at a larger scale necessitated by new chart scheming. *(Contact: J.V. Crowley.)*

The charter vessel *Polar Circle* continued the survey of a deep-draught shipping corridor through the Beaufort Sea. This corridor is 10 nautical miles (nm) wide and approximately 170 nm in length and runs through an area known to contain Pingo-Like-Features (PLFs). This survey was commenced by CSS *Hudson* last year and is now approximately 86% sounded with completion expected next year given reasonable ice conditions. *(Contact: J.A. Vosburgh.)*

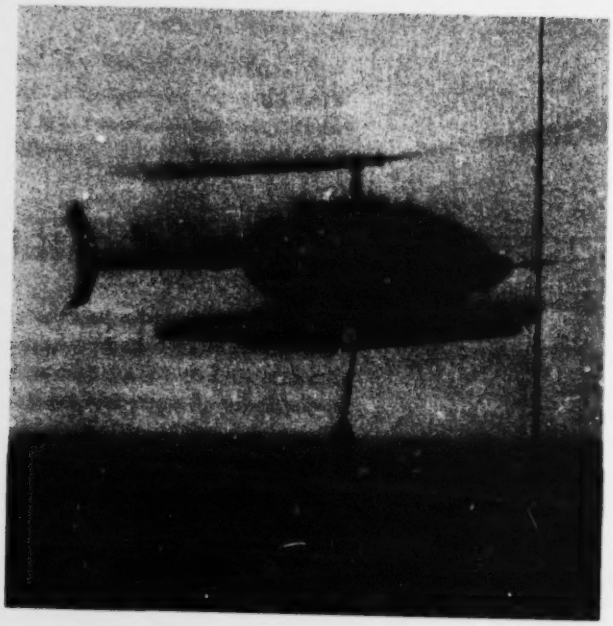
Launch BOLD at high speed in Beaufort Sea.

Several small local revisory survey projects based at IOS were carried out during the summer and a complete resurvey of James Bay, Victoria Harbour was carried out after the return of the major parties from their scheduled projects. This survey which was not on our program but requested by the Department of National Defence (DND), was necessitated by the Royal visit to Victoria, scheduled for March 1983, which entails berthing the H.M.Y. *Britannia* at Ship Point Wharf in the Inner Harbour. *(Contact: B.M. Lusk.)*

The Navigation Group continued Loran-C calibration work. This year's efforts were directed towards the approaches to Prince Rupert where an increase in shipping is expected. An evaluation of ultra-high frequency positioning systems was undertaken in conjunction with Altantic Region's Navigation Group. These systems appear to have several potential applications to hydrography.

In mid-September the region's Navigation Group carried out further monitoring of the Loran-C patterns in the southern Vancouver Island area. These investigations will supply correct time delays and more accurate propagation information for new, latticed charts in southern areas. Early in the year, this same group carried out Accufix/Loran-C investigations in the western Arctic to assist future navigation. *(Contact: A.R. Mortimer)*

Surveys for chart and Sailing Directions revisions were carried out under contract.



Removing ARGO site from Baillie Island.

Sailing Directions

The Twelfth Edition of the *British Columbia Coast Sailing Directions (South Portion)*, Volume I, was published in June. This edition includes new information on tidal streams, seabed, vessel traffic management, Loran-C, search and rescue, regulations and port facilities. The chapters covering the Gulf Islands and south portion of the Strait of Georgia were rewritten to conform with new metric charts published for this area in recent years. New photography and several new diagrams were incorporated into this edition. Volume II (North Portion) and Volume I are published in alternate years. *(Contact: Volume I, A. Smith; Volume II, J. Roberts.)*

The Fourth Edition of *Small Craft Guide, Volume II, Boundary Bay to Cortes Island*, was also published in June. This edition contains extensive revisions and new photography for the Fraser River and Vancouver Harbour. A new edition of the companion, Volume I, Port Alberni to Campbell River will be published in 1983. *(Contact: L.M. Wakefield.)*

Hydrographic Development

Only minor changes in software were necessary to send the PDP-11 computer system to the Beaufort Sea on board MV *Polar Circle* for another successful season.

Due to the difficulty experienced last year in producing final field sheet plots, a contract was let to rewrite this package to improve the data handling routines, and facilitate user interaction with the program. The basic overplot-removal algorithm was retained. As a result, this year's data were plotted quickly and adequately with minimum frustration.

As a spin-off from the Sterntow Project, a new data logger has evolved to replace PHAS (portable hydrographic acquisition system). A contract has been let to extensively modify the existing PHAS processing software. This will be completed and tested prior to the 1983 field season.

□□□□□ Chart Production and Distribution

There are two main functions of Chart Production and Distribution: to process survey and other data into new or existing charts and publications as quickly as possible, and to ensure that an adequate stock of corrected charts is readily available for all users of Canada's navigable waters.

In addition to chart and publication production and distribution, there is also an on-going education and promotion program, including tours, displays and lectures, aimed mainly at colleges and marine organizations. In 1982, this included participation in the Vancouver Boat Show. Two newsletters and five news releases were issued in 1982, announcing new charts and publications, and a total of 186,000 charts and 69,000 publications were distributed.

Cartographic training continued for production staff in 1982 with four junior cartographers attending the Carto I course and two senior cartographers attending the Carto II course, and four cartographers assisted in hydrographic surveys for periods varying from three weeks to three months.

Nineteen eighty-two was a very busy year in automated cartography. The system was heavily loaded with digitizing, editing and data processing. A VAX-11/750 minicomputer system was ordered to provide another graphics work station and which will support up to three stations if required in future.

The RK07 disc drive installed in early 1982 has proven to be very useful since it permits cartographers to digitize one file and edit another file simultaneously. Also, program maintenance and development can now proceed at the same time.

GOMADS (on-line editing and compilation) software was modified to use the old Talos digitizing table as an accurate pointer. It is not yet clear whether the table has sufficient accuracy to permit inputting new information from a graphic. Also during

1982, the production of the Pacific Coast Chart Catalogue was partially automated allowing cartographers to enter the chart limits into a data file and then produce the chart catalogue from it.

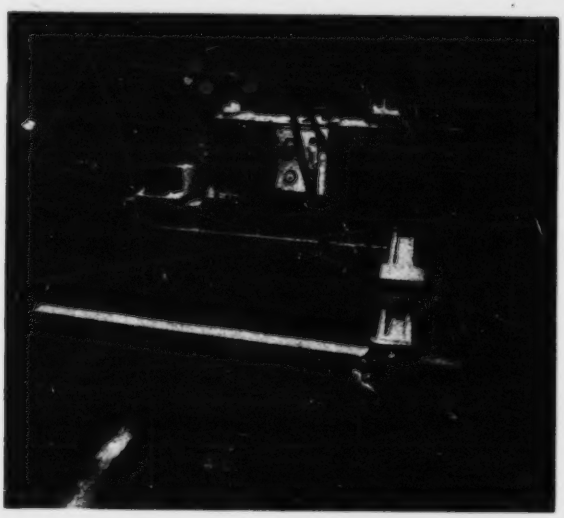
All the digital data for chart set 3311 is now ready for entry into the Digital Data Library. The computer-assisted drafting system lends itself well to charts with overlapping areas and with data displayed in several different orientations. Other charts currently in-hand for computer assistance are 3544, 3461, 3462, 3463 and 3527.

An OVAAC-8 image processing system including an Ikonas display processor, an Imapro colour hardcopy unit, a Century Data 300M byte disc drive, a 1600 bpi mag tape drive, and a small GTCO digitizing tablet, installed on the PDP-11, is now being used by the Chart Production section.

The Chart Distribution office has converted from a key punch card method of data input to a more efficient method by using a Radio Shack TRS80 computer. Data is then transmitted to the Univac System.

On-site inspections of twenty-three dealerships were conducted to ensure adherence to standards. Thirty-nine new dealerships were awarded and twenty-five dealerships were cancelled.

The chart inventory and control system was recently revised to allow for long-range (5 year) planning. This system has proved beneficial in assessing quantities of charts to be stockpiled for specific periods. In addition to the cyclical printing program, which was initiated a few years ago, the production of overprints and 'no date' patches has greatly assisted in reducing the amount of hand amendments required.



Kongsberg Plotter

Tidal and Current Surveys

This program provides tidal, current and water level data, along with other information and expertise, for the Canadian west coast and western Arctic. A permanent and temporary tidal gauging network is maintained for operational and research purposes.

In the western Arctic, a one-month tidal and current survey was carried out in Amundsen Gulf and southern Prince of Wales Strait. Six tide gauges and one current meter were placed and recovered. Data return was excellent. A multi-year program to measure long-term mean sea level variations in waters contiguous to the Arctic archipelago was begun by placing tide gauges in five locations on the outer coast.

Installing a tide gauge through the ice at Isachsen.

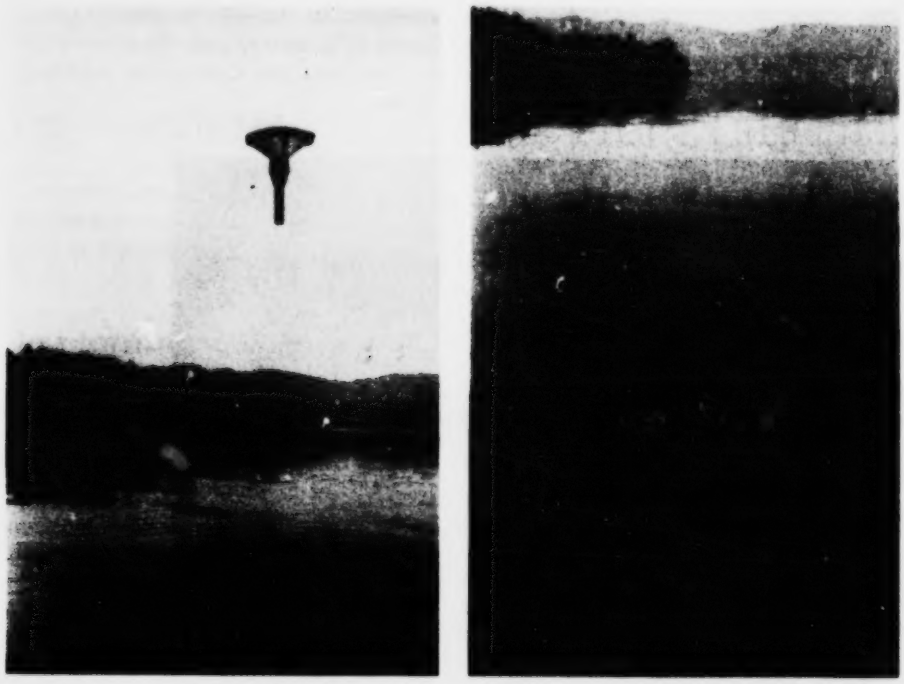
In April of 1982 direct responsibility for permanent tide gauges in the western Arctic was assumed by the Tides and Currents Section. *(Contact: F.E. Stephenson.)*

Major current surveys were carried out in Queen Charlotte Sound and in Chatham Sound near Prince Rupert. Twelve moorings were laid in May and recovered in September. Data reduction, analysis and interpretation is now being carried out.

Inspection, maintenance and operation of several temporary tide gauges and two tsunami warning gauges are being carried out on an on-going basis. Data from these gauges, as well as data from 17 permanent tide gauges operated by Water Survey of Canada, are reduced, analysed and sent to MEDS (Marine Environmental

Data Service) on a routine basis. Tidal Acquisition and Telemetry System (TATS) gauges have now been installed in Victoria, Point Atkinson and Vancouver Harbour and a radio repeating tide gauge was installed in the Vancouver Harbour Master's office.

Final tests were carried out to confirm the usefulness of an oil-spill tracking technique developed in this section. A report on this technique was published. *(Contact: A. Ages.)*



An oil spill marker, developed at IOS, can be "parachuted" to a spill site and then tracked electronically as it moves on the water's surface with the oil.

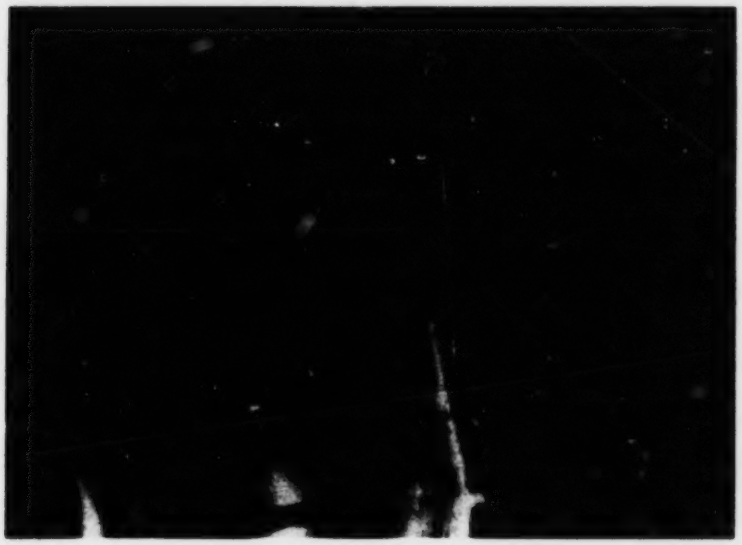
A computer model study of the movement of industrial waste and sewage in the Fraser River estuary was conducted as part of the Federal-Provincial Aquatic Environmental Monitoring Committee program. As a participant on the Environmental Emergency Working Group in the Greater Victoria area, Tides and Currents Section assisted in the preparation of oil spill counter-measures and participated in the prediction and monitoring of two minor oil spills in B.C. coastal waters.

Field and model studies of tides, currents, salinities and temperatures in the Fraser River were continued. The private sector and various government agencies were provided with information and advice on water movement in the Fraser River.

Diving Unit

Diving activity was reduced slightly in 1982, with approximately 100 dives being logged during the year. The number of users of diving services and the variety of tasks performed was about the same as in previous years.

Divers examined various parts of the *Parizeau* and *Pandora II*, observed prototype samplers and release systems in operation, and worked with sediment traps, current moorings and wave measuring equipment. As in previous years many of the dives involved either the installation or recovery of pressure gauges. Major projects in this regard were in Queen Charlotte Sound, Alice Arm and the western Arctic. Closer to home, many dives were also done at the enclosed ocean experiment (CEPEX) site in Patricia Bay.



A replacement current meter is secured to mooring (10 m) at Race Rocks.

Tsunamis

Investigations during 1982 showed that a number of delta fronts in coastal inlets have a history of slumping. Tsunami waves created by these submarine landslides can destroy docks and damage ships and boats. A detailed study is in progress of unusual ridges of the lower slopes of the Fraser Delta, that may have originated from such a sudden massive landslide. Information is being sought on the frequency of occurrence of such events.

The historical study of tsunamis for Canadian west coast ports is continuing. Tsunamigrams from analogue tide records are being systematically digitized.

Spectral analysis routines are being developed to study both the energy distribution of particular tsunamis, and the response characteristics of tide stations. Such studies will provide new information to forecast the tsunami hazards at coastal locations. The study is being coordinated with similar work in other Pacific Rim countries, as part of Canada's contribution to the International Tsunami Warning System.

The Tsunami Unit of IOS is participating with the International Tsunami Information Center (ITIC) in the development of a master plan for the Tsunami Warning System, and in planning for regional warning centres. Warning procedures for Canada's west coast are being developed and coordinated through the B.C. Earthquake and Tsunami Working Group. *(Contact: S.O Wigen.)*

Engineering Services

Engineering Services provides electronic and mechanical engineering, electronics support for hydrographic surveys, oceanographic research and ship operations and an industrial liaison service promoting liaison between IOS and the private sector. *(Contact: T.A. Curran.)*

Engineering Development

This service includes custom development of instrument systems, contract management of government funded private sector developments, and ongoing electronic/mechanical consultations to all IOS groups.

During 1980 a feasibility study to examine the means by which the rate and direction of drifting buoys could be controlled was undertaken. From this study, the concept of active drifters was developed, and subsequently, testing to demonstrate the concept using solar power was initiated. Dynamics of the sterntow system were successfully tested. This hydrogrphic survey package, supported by the High Arctic Research Program (HARP) will produce two to four sounding lines in addition to the ship's track. Fabrication and machining projects included an ice hole melter, various pressure cases, a 20-bottle motorized incubation rack, a gearbox for the "salinity sucker", specialized teflon "bombs" used in chemical analysis, and numerous repairs and modifications to existing prototype equipment.

Many significant electronics projects and project phases were completed during 1982. A multi-channel frequency counter for measuring environmental parameters was completed and applied in the field. A self-contained Aanderaa data tape translator with industry standard RS232 ASCII output was designed, constructed and successfully tested. A similar project was the implementation of a microcomputer-based multi-purpose parallel to serial RS232 ASCII converter. Refinements to Arctic survey launch navigation control were implemented to facilitate use with ARGO positioning equipment in the Beaufort Sea as part of continuing HARP support. Optimization of the acoustic Doppler current meter electronics yielded improved system range, resolution and stability. A portable acoustic Doppler recording system

was developed for use with commercial sounders. A computer system for data acquisition of sterntow survey data was assembled and the software completed under cohtract. The first phase of a Correlation Sonar contract was successfully completed, demonstrating the practical feasibility of measurement of ocean current velocity and ship speed using acoustic remote sensing techniques. Other contract management activity included a ships-of-opportunity temperature and conductivity recorder. *(Contact: J.L. Galloway.)*

Electronics Technology Support

Technical support group activities were directed toward normal maintenance programs involving IOS vessel equipment and equipment used by hydrographic personnel. A major emphasis in 1982 was the planning, installation and field support for electronic survey equipment on the *Polar Circle*'s western Arctic hydrographic survey. West coast surveys with vessels *Pender, Richardson* and associated launches also required technical support. Other staff activities included equipment acquisition, evaluations, modifications, and installations. A remote radio and antenna controller for the IOS radio base station, manufactured under contract, was installed late in the year. A method of improving radio communication during marginal or poor conditions is under study and field evaluations are planned for 1983. Numerous modifications and improvements to commercial survey equipment were implemented. *(Contact: W.R. Taylor.)*

Industrial Liaison and Contracting

The Institute of Ocean Sciences has an established policy of conducting a significant portion of its program through contracts to the private sector. Liaison and support for contracting activities is conducted by the administrative staff of the Engineering Services Group.

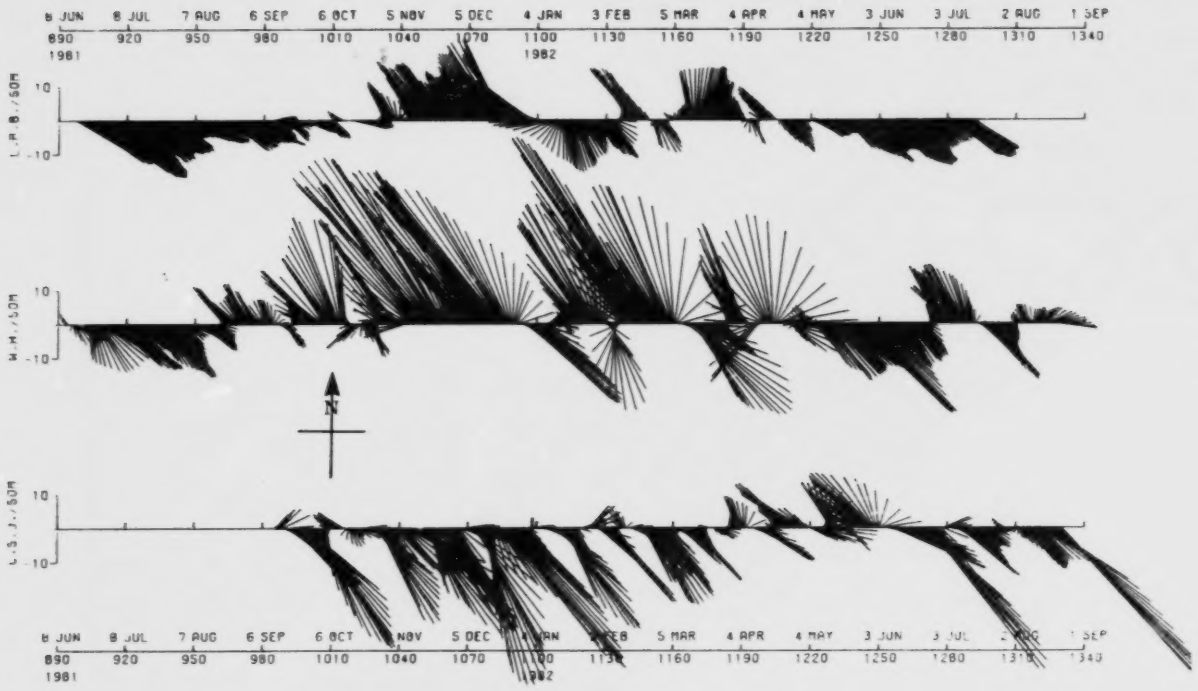
In addition to contracting out directly, IOS participates in such government ventures as the Unsolicited Proposals (UP) program with the Department of Supply and Services (DSS), and both the Program for Industry/Laboratory Projects (PILP) and the Industrial Research Assistance Program (IRAP) with the National Research Council (NRC). IOS was involved to some extent in 92 contracts in the past year, ranging in value from less than one thousand dollars to approximately one million dollars, and with a total value in excess of $5 million.

The UP program has been especially successful at IOS. Ideas for research and development work, originating in the private sector, are submitted to DSS for funding. IOS often sponsors proposals directly affecting its mandate. Proposals must have scientific merit and be clearly unique to justify the waiving of the normal competitive process. Any resulting hardware, software or intellectual rights remain with the Crown.

During the past year, there was one successful PILP, and others in the development stage. This NRC program provides financial assistance to companies to

enable the fruits of government research to reach the marketplace. Under this program, reasonable rights are normally transferred to the participating company under arrangement with the Crown. IOS benefits indirectly by being able to purchase commercial equipment and support.

Another NRC program, IRAP, funds salaries of research professionals to assist small and medium-sized companies to develop commercially-viable products. There was one successful award during the past year to a company performing research of interest to IOS, and other submissions may be upcoming.



Near surface current meter vectors at three locations off the west coast. The locations are (from the top): southern Vancouver Island, northern Vancouver Island and southern Queen Charlotte Islands. On dates, marked below and above the data, the direction of the current flow is given by the direction of the stick and speed, by the length of the stick. Features to note are: the general lack of similarity between different sites, the unusual pulsing of the Cape St. James current with a period of 12 days, and the annual cycles at the two sites bracketing Queen Charlotte Sound are almost exactly 180° out of phase.

The oceanographic program at IOS includes ocean physics, ocean chemistry and ocean ecology. The oceanographic information on current systems and associated temperatures and salinities, on the chemistry of the ocean and associated pollutants, and on primary productivity and the lower trophic levels of the food chain, such as plankton, are provided to agencies engaged in environmental protection, to fisheries managers, to industrial concerns, defence, and to others who have a need for information about the oceans.

Ocean Physics

This year saw the scientists of the Ocean Physics Division engaged in a broad spectrum of activities. Major observational programs were conducted in the Northwest Passage, along the B.C. coast as far north as the Queen Charlotte Islands, and in Observatory Inlet. Other field work included a cooperative study of the oceanography of the Great Barrier Reef, and a survey of McMurdo Sound to examine the effect of supercooling by the Ross Ice Shelf on surrounding water masses. The interpretation of data from earlier observations and associated development of theories and models continued at a frantic pace. One interesting activity has been the involvement of IOS scientists in international efforts to improve storm surge forecasting in the Bay of Bengal, as affecting Bangladesh.

The most important change was the arrival of two new scientists to work on theoretical aspects of general ocean circulation and the role of the ocean in climate dynamics. This will significantly increase overall Canadian activity in this area of current concern, and will permit the oceanographic community to respond more effectively to the needs of meteorologists studying climate variability.

Coastal Zone Oceanography

Analysis of data collected on the southern Vancouver Island Continental Shelf continued during 1982 in conjunction with the Ocean Ecology Division. A description of the statistical structure of oceanographic fields on a continental shelf is emerging that is internally consistent with the known dynamical structure of those fields. This will permit the development of an internally consistent set of covariance functions which in turn will facilitate the problem of the mapping of oceanographic fields in an objective manner. *(Contact: H.J. Freeland.)*

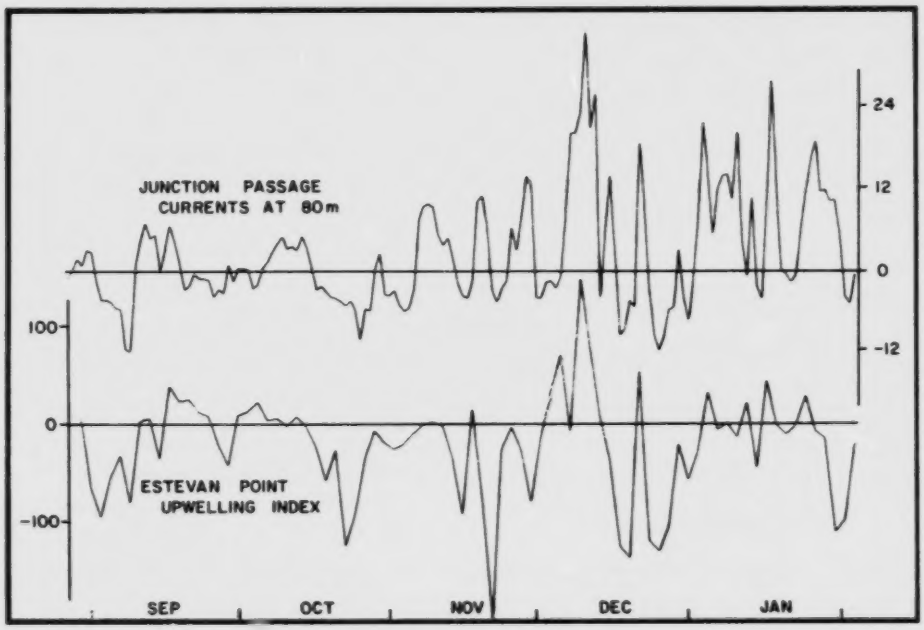
During 1982 the contribution to SUPERCODE was terminated after 1½ years. The total data return rate from moorings during this experiment was 96.1%.

SUPERCODE was a large international experiment to search for low frequency signals propagating along the continental shelf wave-guide. Preliminary investigation

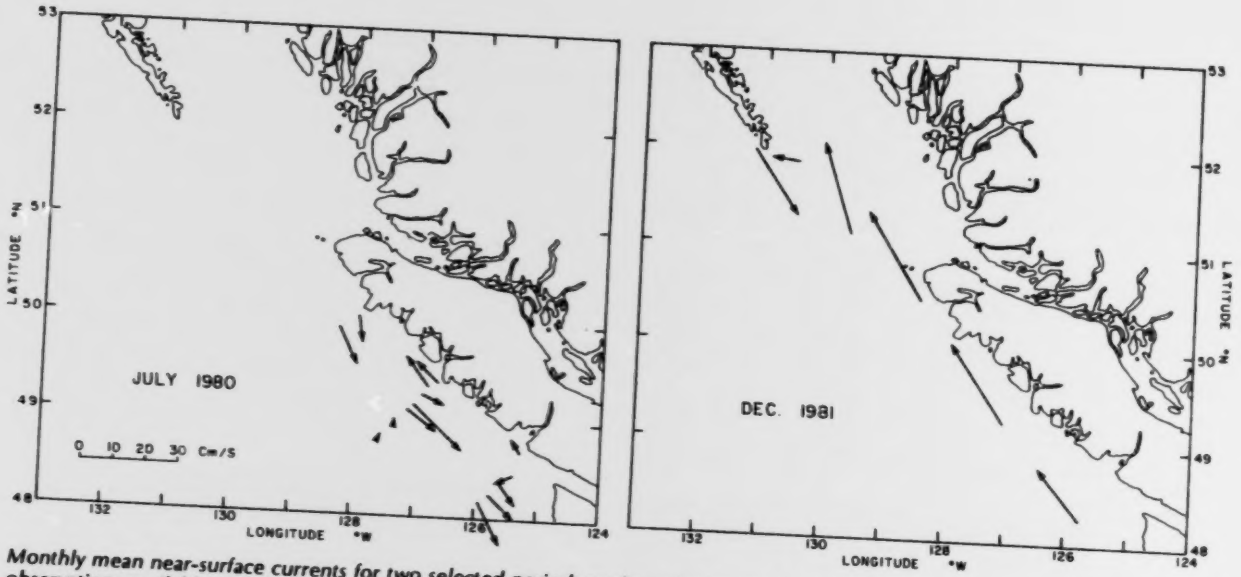
indicates a number of surprising features some of which are illustrated in the current meter "stick-plot" shown here. Even though the southernmost Canadian mooring shows substantial coherence with a mooring off Crescent City (N. California), all coherence appears to be lost over the next 200 km along the west coast of Vancouver Island. The current field off Cape St. James (west coast of the Queen Charlotte Islands) shows a current system qualitatively different from that observed anywhere else. It is hard to see what physical processes can be acting to produce such radically different flow patterns over such short along-shore displacements.

Despite this apparent lack of order, a large-scale overview of the circulation off the west coast of B.C. is emerging as a result of the various large programs carried out by the Coastal Zone, Offshore Oceanography and Tides and Current Survey groups over the past 4 years. We are developing a picture of a current which we have named the Vancouver Island Coastal Current which appears to show remarkable similarities to the Norwegian and Alaska Coastal Currents. *(Contact: H.J. Freeland.)*

Studies of fjord circulation continued with preparation of a review of the physical oceanography of fjords and analysis of shear flow instabilities in the vicinity of sills. In response to concern over mine tailings disposal problems, field effort shifted from Knight Inlet to Observatory Inlet and Alice Arm. Analysis of the estuarine circulation in Alice Arm, based on the daily time series of CTD observations taken during the summer of 1981, has shown that there is little relationship between local run-off and



Low passed inflow/outflow currents measured near Junction Passage and upwelling index calculated from Estevan Point wind data.

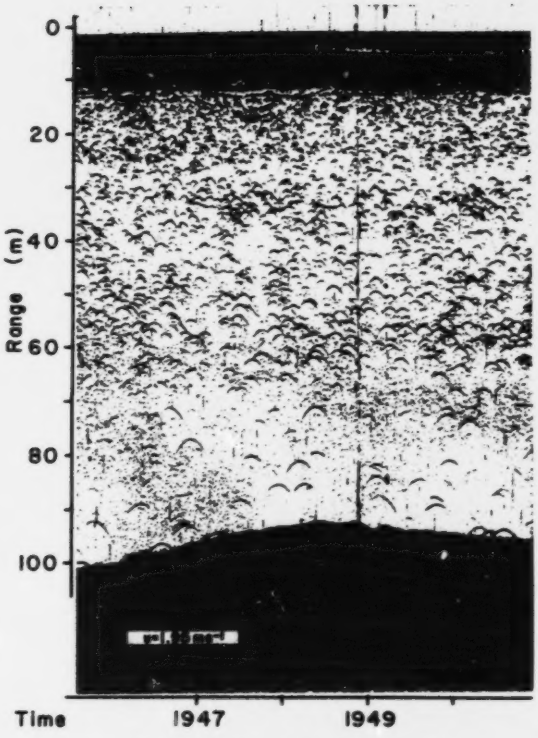


Monthly mean near-surface currents for two selected periods to show the range of observations available. The July 1980 map clearly shows the existence of the Vancouver Island Coastal Current which we believe is driven partly by flow out of the Juan de Fuca Strait and partly by local runoff producing a seaward buoyancy flux. A southward jet along the shelf edge is also visible and appears to be a typical summer feature. The December 1981 map shows some degree of consistency between all sites (except Cape St. James) at very low frequencies. A strong northward flow moves along the coast of Vancouver Island in winter becoming more intense as it does so. However, at the northern end of the entrance to Queen Charlotte Sound the current weakens and turns and we see an intense southward flow coming down the west coast of the Queen Charlottes. This produces an intense shear across the entrance to Queen Charlotte Sound.

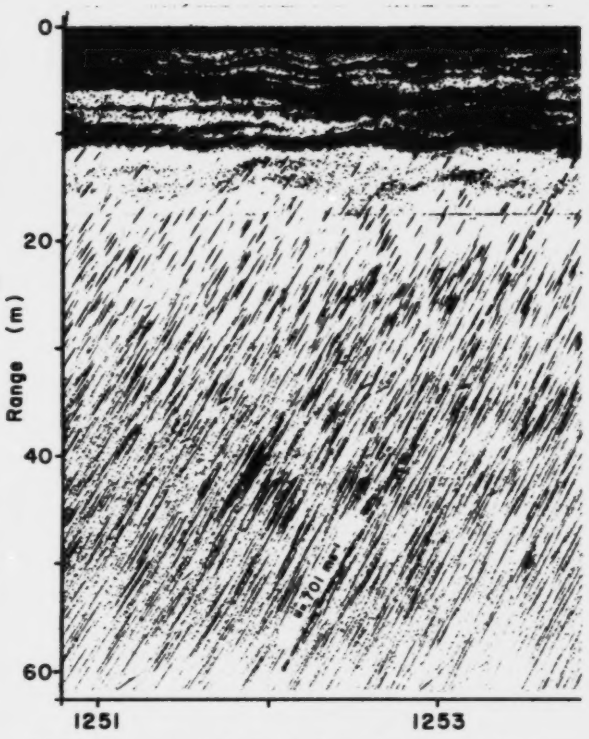
winds and the fresh water content or upper layer thickness in Alice Arm. The forcing of the circulation in Alice Arm, therefore appears to be from outside, i.e. Observatory Inlet. The deep and intermediate water exchanges are also forced from outside the fjord. Deep water renewal which occurs between January and March is coincident with strong outflow winds in Observatory and Portland Inlets. Intermediate water renewal occurs in the summer and is precipitated by the deep water renewal in Observatory Inlet. Investigations are continuing on the internal resonant response of Alice Arm to tidal forcing. *(Contact: D.M. Farmer.)*

Analysis of intermediate water exchanges between Alberni Inlet and the adjacent coastal sea have demonstrated their dominance over the circulation of Alberni Inlet during the winter months. These large exchanges have, in part, been explained and modelled by forcing of the fjord by wind-induced upwelling on the adjacent continental shelf. They may also be forced by fluctuations in the Vancouver Island coastal current. Renewal of the deep basin waters of Alberni Inlet occurs during the summer upwelling seasons; however, the events in these renewals have been shown to be unrelated to wind events or current features on the adjacent continental shelf. *(Contact: D.J. Stucchi.)*

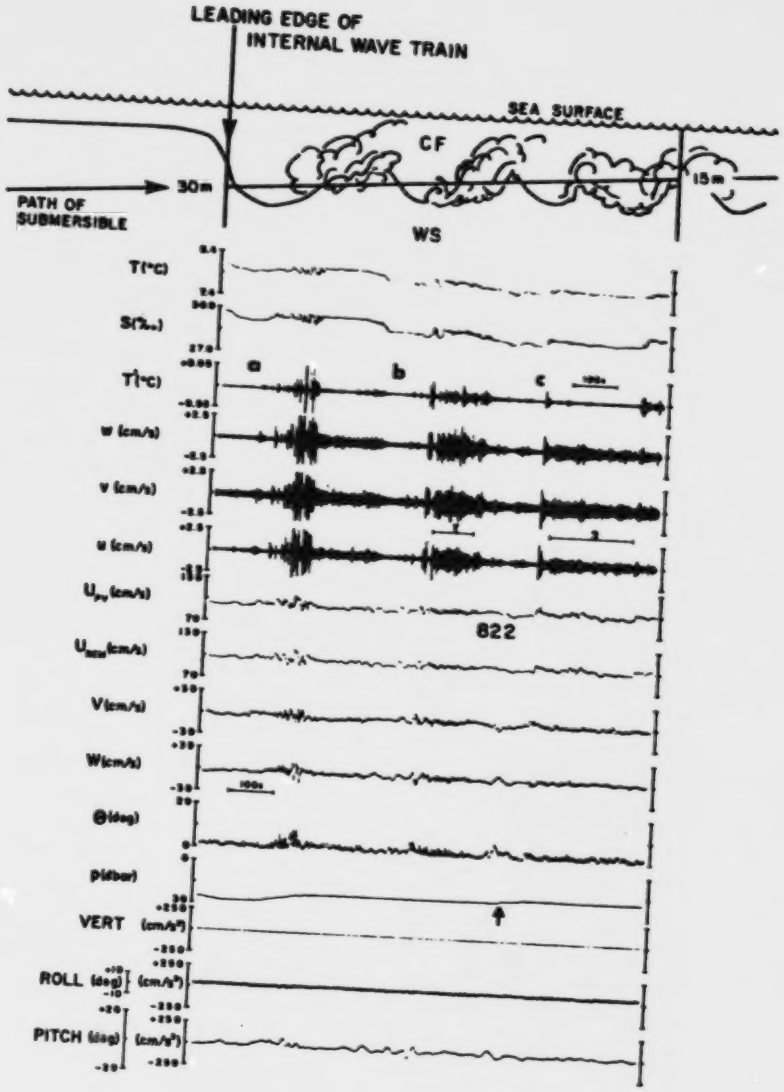
As part of a developing program in ocean acoustics, measurements were taken with sonar devices designed to explore Doppler and correlation techniques. Observations in Alice Arm demonstrated the very low levels of random motion exhibited by scatterers near the inlet head ($u' < 1.2 cm\ s^{-1}$) and both Doppler and correlation techniques provided a detailed description of sill flows in the vicinity. The first tests were carried out with the echometer, a device originally designed for remote measurement of temperature profiles in the atmosphere and now being tested in the ocean. A successful test of ambient noise measurements was carried out in Queen Charlotte Sound. In addition to accurate and continuous measurement of wind speed, the listening devices also allowed the first unambiguous use of ambient noise to provide a measurement of precipitation, separable from the wind record by virtue of its unique spectral signature. The acoustics program has now been extended to include graduate students through a program with the Physics Department at the University of Victoria. *(Contact: D.M. Farmer.)*



(a) Curved traces made on an echo-sounder recording by small targets, probably zooplankton, as they move beneath the ship. The shape and curvature of the traces can be used to recover their speed and thus generate a profile of speed against depth.



(b) These traces are similar to those shown in (a), but are made with a narrow beam echo-sounder pointing forwards. Correlation calculations not only give the speed as a function of range (about 0.7 ms^{-1} in this image) but also allow calculation of the fluctuation velocity component.



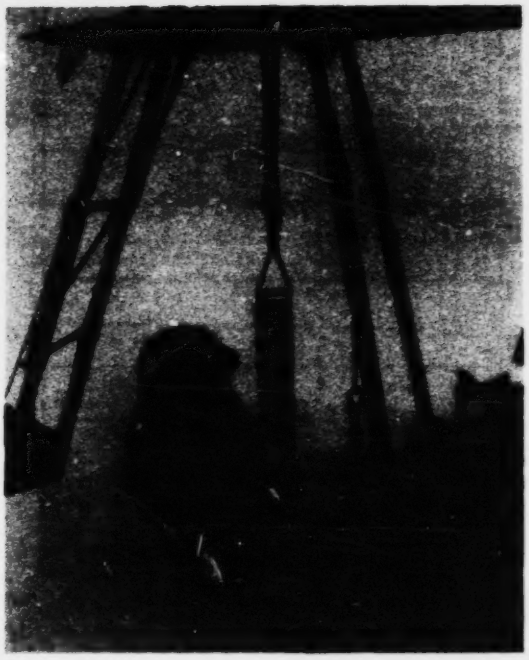
Records of variables measured by the turbulence package on Pisces IV, as the submersible travelled through the leading edge (left-hand side) and subsequent waves of an internal wave train in Knight Inlet, B.C. The cartoon at the top is consistent with fields directly measured along Pisces' path and with high-frequency acoustic images of turbulent structures with similar wave trains. Measurements of dissipation-scale temperature (T') and orthogonal velocity components (u, v, and w) indicate the highly turbulent nature of flow in the trailing edges of waves in the train.

During 1982, much of the turbulence data obtained from the *Pisces IV* submersible operating in Knight Inlet, B.C. was analyzed. A detailed examination of the three-dimensional velocity measurements (in preparation) will clarify the degree to which turbulence in a stratified fluid achieves isotropy by dissipation scales, thus allowing estimation of turbulent kinetic energy dissipation rate from measurement of a single component of the dissipation tensor.

A prototype FLY (*Fast Light Yo-yoing*) profiler for measuring in the upper ocean was built, with modifications to plans supplied by Dr. N. Oakey of the Bedford Institute of Oceanography. This profiler will be used in association with the CZO acoustic Doppler system to investigate the connections between energy-containing and dissipation scales of turbulence. A semi-automated procedure for dealing with the large quantities of data expected from the FLY system was also devised and tested during the past year. *(Contact: A. Gargett.)*

Frozen Sea Research

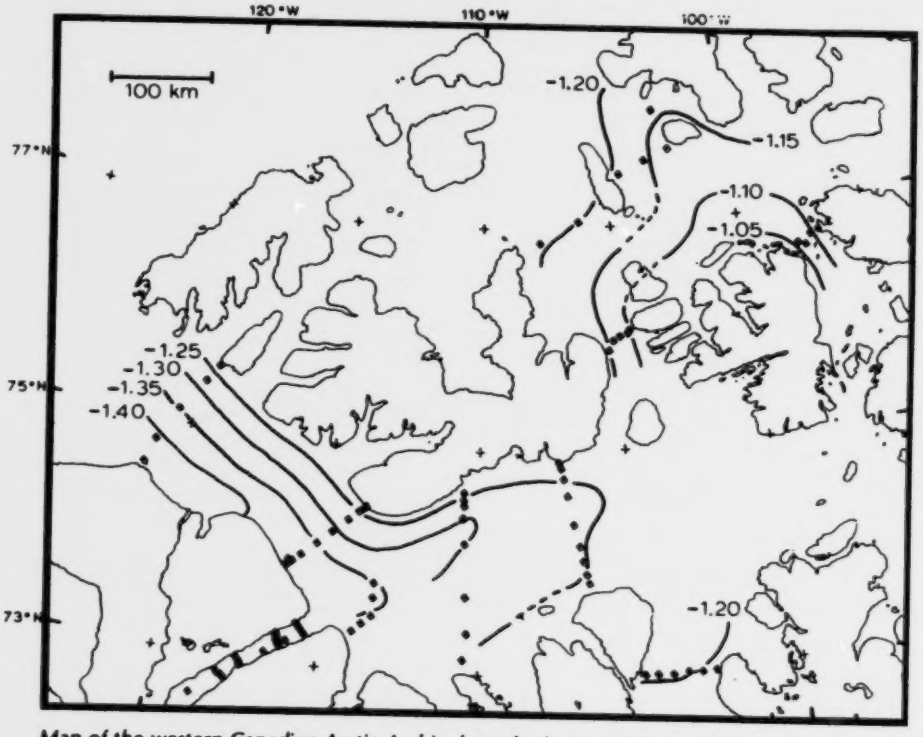
The Frozen Sea Research Group undertook three field operations during 1982: the first, in conjunction with the studies of the Northwest Passage (Transport R&D); the second, a "channel flow" experiment aimed at acquiring a year-long record of near-surface flow in an Arctic channel by a method less subject to instrument damage by ice than direct current measurement; and the third, oceanographic investigation in the vicinity of the Ross ice shelf in Antarctica, as part of a U.S. National Science Foundation project.



A current meter array being deployed in Austin Channel in the Northwest Passage will record data on the seasonal variability of flow for a twelve month period.

The Northwest Passage observations were carried out in conjunction with the Bayfield Laboratory and CHS, Central Region. IOS studies centred on the western

part of the Parry Channel; while contracted work included a CTD survey which covered most of the channels in the archipelago, with a concentration of effort in Amundsen Gulf. Observations included surface currents, water level measurements, and CTD profiles in western Viscount Melville Sound, M'Clure Strait and Prince of Wales Strait. Data analysis is underway and two long-term moorings will be recovered from M'Clure Strait in the spring of 1983. The channel flow experiment used pressure height gauges placed on both sides of Prince of Wales Strait at 20 m depth to estimate flow at that level. During the spring of 1982 a string of current meters placed across the Strait at the same depth was utilized to determine directly the width-average flow at that time and hence calibrate the differential pressures measured by the gauges. It is anticipated that a year-long record from these gauges, to be recovered in August 1983, will allow the corresponding variations in flow to the inferred. *(Contact: R. Lake, H. Melling.)*



Map of the western Canadian Arctic Archipelago displaying isotherms (°C) for water of salinity 33.5 (approximately 150 m depth). In the Arctic Ocean waters of this salinity have temperatures less than ~-1.4°C, and form part of the cold, nearly isothermal pycnocline which is maintained by freezing processes in peripheral shelf seas. Within the Archipelago these freezing processes are no longer important, and the waters entering from the Arctic Ocean are able to warm as they move eastward because of thermal diffusion from below. Near the shallow (~100 m) sills restricting passage beyond the eastern edge of the map, waters almost 1°C above freezing are accessible for mixing to the surface by the energetic flows over the sills. It is this reservoir of heat which inhibits sea ice formation downstream of the sills and maintains the polynyas for which the area is well known. (Data from the 1982 Northwest Passage Oceanography Program.)

The contracted CTD survey is the most comprehensive survey to date covering the archipelago as a whole. Preliminary results show, for the first time, a systematic increase in temperatures within the pycnocline from west to east as the flow of water from the Arctic Ocean moves towards Baffin Bay. The warming appears to be a consequence of upward diffusion of heat from the Atlantic layer which is not counteracted by the draining of freezing water from the adjacent shelves as is the case in the Arctic basin. Mean surface flows are weaker than had been expected but vertical shears are significant. *(Contact: H. Melling, R. Lake.)*

Studies in Anarctica, which took place between October and December, included a complete CTD survey of the McMurdo Sound and detailed studies of the formation of anchor ice on the seabed. Surveys were conducted moving away from the Ross Ice Shelf to show the effect of this major ice face on the surrounding water masses. Data is presently being reduced. *(Contact: E.L. Lewis.)*

During 1982 the documentation of studies of a polynya in the Canadian Arctic Archipelago was completed. Three papers on the subject discussing respectively the oceanography, the atmospheric turbulent heat flux, and the total heat balance of the Dundas Island polynya during the winter/spring period, will appear in the Journal of Geophysical Research in 1983. *(Contact: D.R. Topham.)*

Work was also completed on the formation of gas hydrates during oil well blowouts at depth and its implication in terms of the circulation resulting therefrom. Staff also became involved with experiments to determine the possibility of subsea containment of underwater oil well blowout. Advice was requested on experiments carried out in Florida during February 1982 and on the subsequent interpretation of results. A major portion of the study on the transfer function of conductivity cells from conductivity-temperature-depth instruments was completed. This work is of particular importance to the interpretation of oceanographic data taken in the presence of fine structure in temperature and salinity. A start was made towards the planned study of ice/water/topography interactions in shallow Arctic seas while laboratory experiments were carried out to investigate dense convection currents along a sloping bottom. These small scale experiments illuminate observations made in nature on a much larger scale. *(Contact: D.R. Topham.)*

Study of data from the Beaufort Sea resulted in the publication of a paper on shelf drainage and its relationship to the Arctic Ocean pycnocline.

A preliminary study of data from the EUBEX (a joint IOS-University of Washington Eurasian Basin survey) showed that a surface heat loss from the Atlantic waters entering the Arctic Ocean through Fram Strait occurred in two locations, close to the shore of N Svalbard and about 300 km offshore. Supercooling of surface waters was frequent and appears associated with the presence of pressure ridges and the dependence of freezing point on depth. It will have a significant effect on air/sea energy exchanges at high latitudes especially in leads and cracks. *(Contact: R. Perkin, E.L. Lewis.)*

Many of the instrument developments carried out in 1982 were to aid oceanographic surveys conducted over the sea ice from helicopters. A lightweight

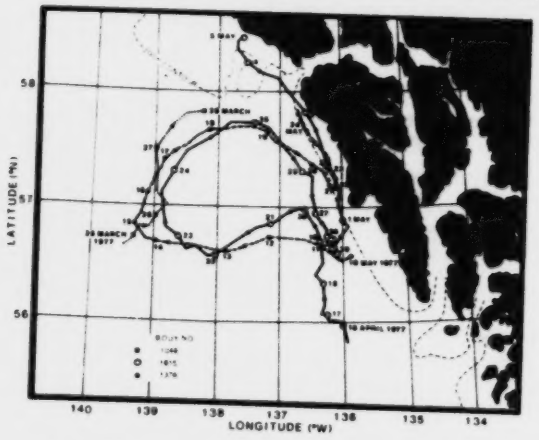
CTD winch was developed which allows observations to be made down to 500 m. Another component of the helicopter CTD system is a more compact deck unit built utilizing Guildline components having the tape recorder in the same chassis. Modifications were made to all support equipment, including range-range navigation, echo sounder, radio beacon, drilling bit assembly and power head, etc., to make them lightweight.

A major project has been the redesign of the front end of the Guideline CTD. This has been done in an attempt to improve sensor flushing and also to make the relative positioning of sensors conform to recommendations contained in the recent report of Perkin and Lewis (1982). Tests on this new design, to date successful, are continuing.

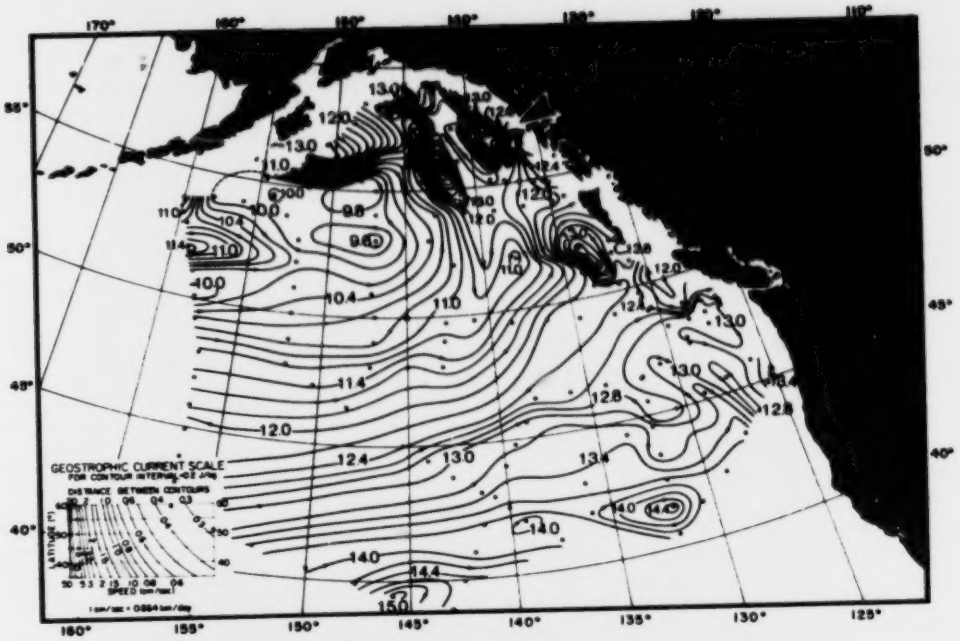
Offshore Oceanography

A total of eight cruises along Line P and two other lines, between the Canadian west coast and Station P was made during August 1981 through November 1982. These observations are made, in part, to complement the 22 years of time-series measurements along Line P and also to determine the relationship between the water properties along Line P and along the other lines. *(Contact: S. Tabata.)*

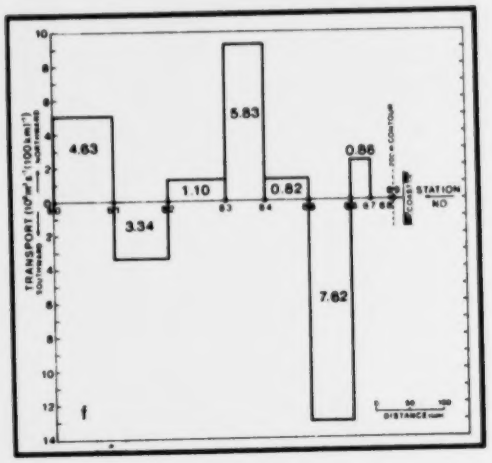
Oceanographic data collected in the Gulf of Alaska during 1947-1975, together with drifting buoy data, has revealed that a well-developed, anticyclonic, baroclinic eddy frequently recurs in a particular area a few hundred kilometres west of Sitka, Alaska. Atmospheric forcing and topographic interaction in combination appear to be the main generating mechanism for the eddy. *(Contact: S. Tabata.)*



Three NORPAX satellite-tracked drifting buoys came into the vicinity of the Sitka eddy during March-May 1977. They entered the area of the eddy, each at different times—March, April and May. Yet their trajectories all appear to have described at least a part of the eddy circulation. The average surface velocity of the eddy, as estimated from the buoy drifts, was 60 cm s^{-1}.



The "Sitka" eddy is shown as it occurred in 1961. During 1954-1962 it has been observed for 6 years. A similar but lesser eddy occurred 300 km to the southwest of the main one. The contour lines are geopotential anomalies at the surface relative to the 1000-decibar surface in J kg^{-1} (from whose gradient the surface baroclinic current velocity can be estimated).



Baroclinic transports across a section through the two anticyclonic eddies. The average baroclinic transport (relative to the 1000-decibar surface) of the Sitka eddy is 5 sverdrups (5 x 10^{6}m^{3}s^{-1}). Maximum transport of 7.6 sverdrups occurred during 1961. The smaller eddy has only one half the transport of the main eddy.

Time series measurements of temperature and salinity profiles taken in a 40 km triangle around Ocean Station P since 1978 are being examined in order to assess the effect of advection on the time-changes of properties of water at Station P. The correlation between the advective velocity determined from the scalar field and the time-integrated atmospheric stress field is being compared with the results of time-dependent baroclinic adjustment theory. A study of the response of the upper ocean to extratropical storms in the North Pacific is being continued. *(Contact: M. Miyake.)*

The reduction, analysis and interpretation of data taken during the Coastal Ocean Dynamics Experiment (CODE) continued during 1982. An analysis of baroclinic and barotropic semi-diurnal tidal currents for the west coast of Vancouver Island continued, as did a comparison of observations with baroclinic and barotropic models of diurnal period continental shelf waves for the west coast of Vancouver Island. A study of the temporal variability of near-inertial current oscillations and the importance of these currents to mixing of surface waters and the low-frequency variability of currents seaward of Vancouver Island including possible existence of topographic waves and seasonally forced, baroclinic Rossby waves was undertaken. *(Contact: R.E. Thomson.)*

Satellite-derived sea-surface temperatures for 1980 through 1982 are being examined to delineate detailed circulation off the coast of B.C. Marked differences in the circulation were found. For example, while the January 1979 data indicated a presence of a jet of cool water directed southward, the January 1980 data showed a well-defined jet of warm water was directed northward.

In cooperation with several Australian scientists, a study of the physical oceanography of the Australian continental shelf in the area of the Great Barrier Reef was carried out for comparison with conditions on the B.C. shelf. *(Contact: R.E. Thomson.)*

Theoretical projects also in progress are: research on weakly interacting internal waves which seeks a theoretical description of finite amplitude interactions among internal waves and geostrophic motions and of their relation to smaller scale, stably stratified turbulence; and, an examination of the efficiency of mesoscale eddies to produce parapycnal transport, including effect of planetary wave propagation and of underlying topography. Also, a study was completed which shows that Rossby wave propagation and finite equivalent depth of a barotropic atmosphere each enhance the predictability of an atmosphere. *(Contact: G. Holloway.)*

A study of the use of *decision theory* in geophysical forecasting; application of functional analysis to investigate the predictability of quasigeostrophic motion; an examination of the effects of low resolution on numerical simulation of turbulence; development of inverse methods for assimilating data into numerical ocean models; and estimation of meridianal heat flux in the N. Pacific Ocean based on XBT data were also advanced *(Contact: A.F. Bennett.)*

Numerical Modelling

In the course of joint three-dimensional model studies with the University of Hamburg, gross features of the mixed tidal regime, and of the interacting tidal residual and density driven circulation, in the bathymetrically complex, variously stratified system of straits and passages between Vancouver Island and the mainland have been reproduced. *(Contact: P.B. Crean.)*

Special interpolation of velocity vectors obtained from surface drogues (2 m depths) has permitted coherent definition of velocity fields in the shallow plume formed by the tidally modulated Fraser River discharge spreading over the denser water in Georgia Strait. The data, together with concomitant boat and helicopter STD survey, are being used in the development of a buoyant spreading upper layer tidal numerical model. *(Contact: P.B. Crean.)*

Irregular triangular grid models of Dixon Entrance, Hecate Strait and Queen Charlotte Sound for tides and storm surges are being developed. The modelling of tides in the Bay of Bengal, requested by the World Meteorological Organization was completed. A storm surge book manuscript was modified following the reviewer's comments and the final draft was submitted for publication. Some synoptic studies on explosive development of extra-tropical cyclones in the northeast part of the Pacific Ocean were completed. *(Contact: T.S. Murty.)*

An automated computer program was developed for modelling linearized shallow-water problems with an explicit finite difference method. A corresponding nonlinear version is being developed. A model of shelf and Kelvin waves was developed for comparison with observations off Vancouver Island. Analyses and tests of the phase and group velocity characteristics of various finite element numerical modelling scheme are continuing. *(Contact: R.F. Henry.)*

Remote Sensing

Following work on remote measurement of chlorophyll fluorescence at IOS, construction commenced on a fluorescence line imager, designed to provide improved data in airborne surveys of primary productivity in a joint DFO and ICS (Interdepartmental Committee on Space) enterprise. The instrument will provide improved sensitivity and spectral resolution for water colour mapping and will be used to evaluate the possibility of chlorophyll fluorescence mapping from space. The instrument will be ready for flight tests in 1983. Work at IOS continues on analysis of water colour data from existing U.S. satellite and airborne equipment. A joint Canada/German field experiment (FLUREX) provided remote and *in situ* measurements of chlorophyll fluorescence in the North Sea and Baltic Sea in April 1982, and further experiments are planned to prepare for use of the new imager in 1983. *(Contact: J.F.R. Gower.)*

An image producing system (IKONAS interactive display with OVAAC-8 and University of Miami software on a PDP-11/34) was installed at IOS in October for display and analysis of satellite data. It is already finding applications with a variety of other image data from numerical models and acoustic sounding.

Computing Services

A Data Communications Study was performed in the summer of 1982. This confirmed that data communications were significantly out of date and limiting. The existing Gandalf MiniPACX computer exchange (with a fully utilized capacity of 48 incoming circuits) was upgraded to a COMPACX IV (with an upper limit of 128 lines, and other advanced features to meet the requirement for a greater number and variety of terminal connections). Also a Univac DCP/20 front-end Communications Processor has been ordered to replace the now obsolete CTMC (retained from the old Univac 1106 configuration), which will allow higher speed computer graphics, protocol flow control to intelligent devices and non-standard device support.

In April 1982, DATAPAC access to the Univac system was expanded to four channels (via a PIN9102 depacker). System developments included a change in the batch scheduling algorithm to give higher priority to jobs with shorter estimated run times. Maintenance and updates to system libraries and processors continued, including the installation of version 2.95A of System 2000 (database management). In addition, a high level Graphics package was obtained from the National Centre for Atmospheric Research (NCAR) and implemented on the Univac and the Tektronix Interactive Graphics Library was acquired.

A Floating Point Systems AP190L array processor became fully operational in September 1982. Utilization of the AP reached a high of four users (logging 117 hours in December) with computationally-intensive numerical problems. A second remote batch terminal (in the form of a used Comterm 1000) was purchased and installed in the Computing Services wing of the IOS main building complex providing much better access for remote job entry and output to the several groups located nearby.

An assessment of the user workload showed an apparent increase of 9% in 81/82 over the previous year. However, accounting for a unit price reduction of 30% in processing charges and 80% in file storage charges, the actual workload increase was a factor of 2, reflecting the greater processing power and storage capacity of the new system.

In September a new resource control system for Univac users was implemented. The total cost, including rate factor and connect-time charges, is displayed at the end of a run and charged immediately against the user's allocation.

To facilitate the procurement process for an increasing number of system analysis, programming, and data processing contracts, Standing Offers for EDP Professional Services totalling over $300,000 were established with three firms.

Developments of data base applications using the System 2000 DBMS on the Univac system was accelerated. For the Library Book Catalogue, reporting programs to print the various catalogues were enhanced and completed; output is now to magnetic tape from which microfiche is prepared by an external service. The database input program was modified to be tabledriven; this has facilitated the implementation of several new applications. These include bibliographies and inventories of oceanographic data, primarily for the Pacific coast and western Arctic (Beaufort Sea) regions, for the Ocean Information Division. Management Services converted to System 2000 for two record keeping applications. Other new users included Frozen Sea Research Group, Ocean Ecology and Personnel Divisions. (Contact: K. Teng.)

Central computing facility at IOS; showing the Univac 1100/60.

Ocean Chemistry

The major objective of the Ocean Chemistry Division is to provide expertise, advice and a scientific perspective on both short-term and long-term problems associated with the chemical aspect of the ocean environment through both monitoring and research activities. Five areas are of prime concern: ocean pollution, ocean climate, ocean fluxes, ocean circulation and ocean productivity. The major effort is directed towards basic scientific understanding of the long-term consequence of anthropogenic manipulation of the natural environment, but a balance is also struck by studying the short-term environmental impacts of societal intrusion.

A benthos gravity corer being deployed in Observatory Inlet for the dating of sediments.

Amax

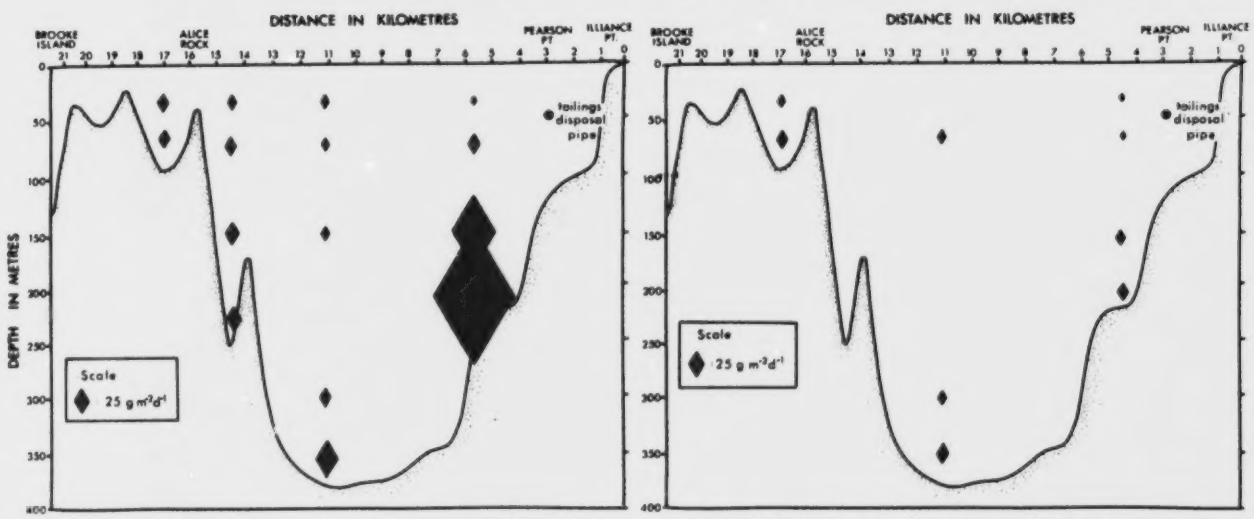
In response to a requirement for baseline levels and processes affecting the distribution of tailings disposed into Alice Arm, as pointed out by the Amax Mine Review Panel, a crash program was launched to provide new knowledge through research and monitoring studies.

The chemical program consists of four components: the determination of trace metal levels in the sea water column of Alice Arm and in inlets in the vicinity, a study of metal build-up in pore waters of bottom sediments polluted by mine tailings, a laboratory study of the metals released from tailings suspended in sea water and the establishment of sedimentation rates of mine tailings and metal content of particulates collected by sediment traps.

Cruises were conducted in the Alice Arm area to obtain seasonal pictures of chemical oceanographic variabilities, to determine fluctuations in natural inputs of metals in particulates and in mine tailings inputs, to launch and retrieve sediment traps, and to sample pore waters and sediments.

Sediment and pore water studies are in progress with the analysis of core profiles of sediments for a suite of metals (Cu, Zn, Pb, Cd, Mo and Mn) to establish levels for pre- and post-start up of the Amax mine and to assess the metal build-up in pore waters. Preliminary data on the radioactivity of Uranium-238, Thorium-232 and Potassium-40 from Ocean Chemistry Division and from the Pacific Geoscience Centre indicated no elevated concentrations of these nuclides associated with past tailings deposits or current tailings. *(Contact: J.A.J. Thompson.)*

Data from moored strings of sediment traps have led to the conclusion that mine tailings disposed of by the present method seem to settle close to the outfall and that tailings have moved a further distance as a bottom nepheloid layer rather than as a water column plume. Samples from a trapline set within one kilometre of the outfall contained mainly tailings material at 150 m and at 200 m depth, but only 50



percent as tailings material at 70 m depth. No obvious tailings were found in sediment traps set within 10 km of the Amax outfall. *(Contact: R.W. Macdonald.)*

Preliminary data of trace metals in sea water columns indicated that from the pre-dumping period, sea water samples in the Nass River estuary had higher values of total cadmium, lead and zinc than did samples taken in Alice Arm. During a high runoff period in October 1980, there was substantial mobilization of total metals in Alice Arm with a factor of 5 higher in cadmium and zinc and of 10 in lead, compared to the Nass River estuary. A new technique, using lead-206 and lead-207 isotopic ratio to trace the extent of mine tailings contamination in Alice Arm, was developed successfully through an unsolicited proposal by Seakem Oceanography Ltd. The IOS clean laboratory and mass spectrometer were used. (Wong, Stukas.) Dissolved copper in Hastings Arm showed a high subsurface peak at about 70 m compared to generally low values in Alice Arm, thus indicating possible leaching input from an old mine heap at Anyox. *(Contact: C.S. Wong.)*

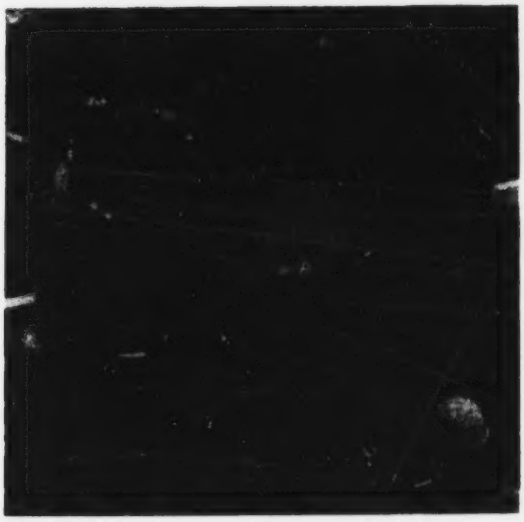
Marine Carbon Research Centre

The Ocean Science and Surveys Marine Carbon Research Centre at IOS, now in its fourth year, is focussing on the marine aspects of the global carbon dioxide (CO_2) cycle by conducting research, monitoring and modelling activities. An emergent consensus of the scientific community which warns of a possible 2-3°C warming due to future CO_2 doubling in the atmosphere with a possible increase of 0.1-0.5°C per decade, has led to an urgent need to understand the mechanism of the global CO_2 cycle. In particular, it is important to study the ocean's capacity to absorb atmospheric CO_2.

CO_2 monitoring is an essential tool in recognizing the first signals of oceanic CO_2 increase and in establishing the secular increase and long-term variability. The ocean CO_2 monitoring program has been using three types of platforms: ships-of-opportunity, research cruises along Line P, and B.C. lighthouses. The ships-of-opportunity program using the *Canada Ace* between Tokyo and Richmond, B.C. and the Lillooet between Sydney, Australia; Noumea, New Caledonia; and Tacoma, Washington continued to provide the CO_2 time series and oceanographic properties of the Pacific Ocean for research and modelling. The Carbon Research Centre also assumed a lead role in organizing an international working group of the Scientific Committee on Oceanic Research (SCOR) on ocean CO_2 monitoring to map out a global strategy and to review various national capabilities for international cooperation. *(Contact: C.S. Wong.)*

CO_2 research in 1982 was highlighted by participation in the *Discoverer* cruise of the Pacific Marine Environmental Laboratory (PMEL) of the U.S. National Oceanic and Atmospheric Administration (NOAA) in western and equatorial Pacific waters. In cooperation with PMEL, air-sea partial pressure of CO_2 was measured using a new gas chromatographic technique. An intercalibration of this IOS total CO_2 method with the PMEL titrator approach was also made during the cruise. CO_2 modelling was initiated with the support of a new postdoctoral research fellow with

activities concentrating on a diagnostic model of Canadian atmospheric CO_2 to establish sources and sinks from the Canadian land forest, and Arctic and ocean reservoirs. CO_2 regeneration processes to convert organic carbon into CO_2 in the marine environment were also initiated with the assistance of a postdoctoral research fellow. *(Contact: C.S. Wong.)*



A deep-ocean sediment trap being deployed at Station P in co-operation with staff from Wood's Hole Oceanographic Institution.

Hydrocarbons and Pesticides

The objective of the program is to advance the knowledge of the occurrence, pathways and fate of hydrocarbons (natural, petroleum-based, chlorinated and pesticides) in the marine environment.

Histological and chemical survey of bivalves was conducted under contract at the Alberni Inlet dump site and in local southern Vancouver Island waters. At the first location, histopathological examination of bivalves and other organisms did not show signs of environmental stresses. In contrast, evidence of stresses was uncovered in southern Vancouver Island waters with mussels from Cowichan Bay showing the poorest histological condition; those from McLaughlin Point, intermediate condition; and those from Hatch Point, the best. Hydrocarbons of intermediate volatility (10-20 carbons in the chain compound) were found to be lowest in mussels from Hatch Point. Evidence of proliferative disorders in mussels in the southern Vancouver Island study area were found with hemopoietic neoplastic disorders being prevalent. A first identification of a gonadal neoplasm disorder was made in *Mytilus edulis*. In contrast to the southern Vancouver Island waters bivalve study, similar studies in the Alberni Inlet and Kitimat areas have failed to find evidence of proliferative disorders.

Instrument development included work on a fibre-optic photoacoustic detector which is being developed in cooperation with the University of Victoria for *in situ* measurement of oil dispersed in sea water. A hermetically-sealed sediment drier which removes water by molecular sieve without losing volatile compounds was designed and built at the Institute for use at room temperature. *(Contact: W.J. Cretney.)*

Ocean Flux

Ocean flux experiments were carried out under two international cooperative programs: SEAFLUXES and PARFLUX. Two SEAFLUXES enclosed experiments were performed. The first was a spring bloom experiment, performed with the participation of Dr. B. Imber of Royal Roads Military College relating to chelation of zinc and with Dr. F. Pollehne of the Institut für Meereskunde at Kiel, F.R. Germany, working on the change of C/N ratio and pigment composition of phytoplankton approaching nutrient or light limitation. The second was a mercury experiment in which two bags were launched in June to study the pathways and fate of mercury in sea water and the effect of biological forcing of phytoplankton growth on mercury distribution. This experiment was carried out in cooperation with Mr. X. Lu of the Shandong College of Oceanology and Mr. J. Wu of the Third Institute of Oceanography at the Chinese Bureau of Oceanography. In August, a working group meeting with representatives from the National Bureau of Oceanography in China, the International Development Research Centre in Ottawa, U.B.C., and officials from both Ocean Science and Surveys in Ottawa and in the Pacific Region was held to define the scope of future Canada/China cooperation in the study of marine pollution dynamics using such an ocean enclosed experiment technique. *(Contact: C.S. Wong.)*

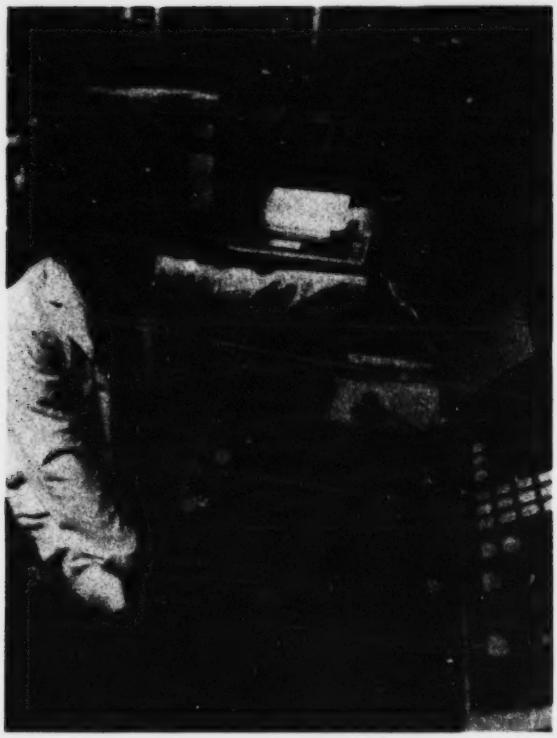
Under the PARFLUX program, a cooperative venture with Woods Hole Oceanographic Institution (Dr. S. Honjo) was initiated in 1982 with the mooring of an automated sequential sediment trap at Ocean Station P (50°N 145°W) in October to study fluxes of metals, hydrocarbons, carbon cycle, and mineralogy/morphology of particles in the open ocean. *(Contact: C.S. Wong.)*

Fjord and Arctic Chemistry

The objective of the program is to gain new knowledge of the environmental factors controlling the circulation and sedimentation in B.C. fjords and in the western Arctic. Such new knowledge will contribute to environmental impact statements and assessment of pollutant effects associated with development of the western Arctic for oil and gas, and with increasing industrial activities in coastal inlets of B.C.

Field activities were devoted mainly to the Alice Arm fjord system as described above. Other activities included the publishing, as workshop proceedings, of previous Kitimat fjord studies, including those by other agencies and IOS divisions covering physics, chemistry, geology, biology and hydrography. The Division also provided scientific authority on Arctic data compilation contracts and coastal data

information contracts. Because of increased drilling acvitivy, Ocean Chemistry scientists were heavily involved in the Beaufort Sea oil production Environmental Impact Statement, in the Risk Analysis of sea and land transportation routes and the disposal of offshore drilling fluids. *(Contact: R.W. Macdonald.)*



Research scientist conducting metal determination of sediments by atomic absorption spectrophotometry.

Coastal Pollution

The objective of the program is to understand the detoxification mechanism of metal-protein complexes (metallothioneins) in marine organisms and their transformation mechanisms and organometallic species in the marine environment so that environmental significance of "pollutants" can be assessed in a meaningful way.

For the metallothionein work, the polarographic technique was further developed with a detailed study of the temperature-dependence of polarographic response. Field study, in addition to that discussed under Amax, includes a cooperative project with the Royal Roads Military College (Dr. K. Reimer) on arsenic speciations in Rupert Inlet involving the collection of a series of sea water and sediment samples for chemical speciation analysis. Another cooperative project with DFO's Freshwater Institute in Winnipeg (Dr. B. Fallis) consisted of an exercise

to evaluate the analysis of clam tissues for lead and other metals associated with the Nanisivik mine monitoring program. Ocean Chemistry Division also provided freeze-dried clam tissue from local sources to a number of Canadian government and commercial laboratories for inter-calibration.

During 1982 there was much demand for Coastal Pollution staff to provide advice and expertise concerning such activities as ocean dumping, the examination of organotin compounds under the National Research Council, the environmental monitoring of the Nanisivik Mine and Amax review panel deliberations. Discussions were also held with various industrial and consulting firms. *(Contact: J.A.J. Thompson.)*

Trace Metals

The objective of the trace metals program is to assess the distribution and fluxes of natural and man-mobilized metals in the ocean, especially their interaction with suspended matter, the planktonic biota and surface sediments.

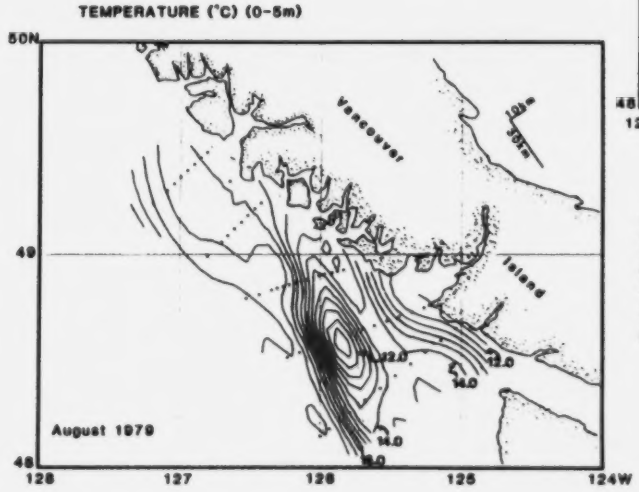
The study priority has shifted from open-ocean to coastal waters to accommodate the Amax program and the demand for knowledge required for ocean dumping decisions. To understand the seasonal cycling of mercury, a time series on mercury distribution in Saanich Inlet was obtained using sediment traps at monthly intervals. Total and particulate mercury, organic mercury, temperature, salinity, POC, oxygen, sulphide and mercury fluxes were recorded. The work was performed as a cooperative effort with a visiting scientist from China, Mr. X. Lu. During the study period, mercury of around 1 $\mu g\ L^{-1}$ total mercury in sea water, lower than any reported value, was observed in the surface waters. A significant build-up of organic mercury was observed in the bottom waters and pore waters of sediment of the Inlet during the sulphide build-up in the summer. Sea water for mercury standard was also collected for certification study both at IOS and at the Jülich Nuclear Research Institute in F.R. Germany. This study is being conducted in cooperation with Dr. Nürnberg on behalf of the IUPAC (International Union of Pure and Applied Chemistry) natural waters program. A long-term storage study of mercury in sea water and a short-term release rate study of mercury from sediment were also conducted. *(Contact: C.S. Wong.)*

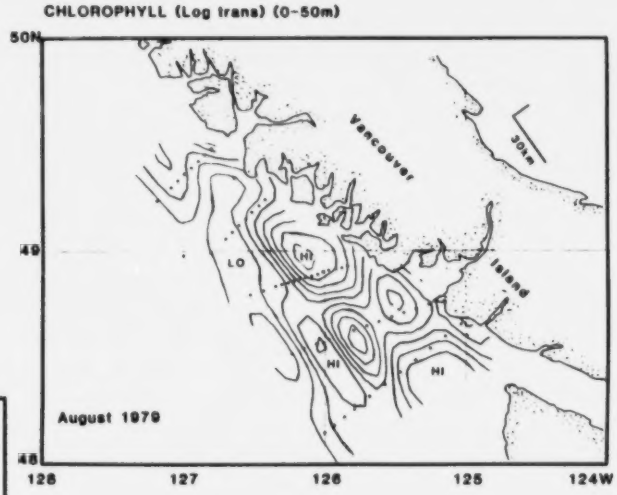
An ocean dumping release experiment was conducted for lead and cadmium using sediments from the False Creek area in Vancouver which are known to be contaminated by high cadmium and lead. The experiment was carried out in the clean room and the metal values were determined by ultra-clean room manipulation and mass spectrometry. The release/absorption characteristics were different at low, medium and high concentrations of metals. For example, cadmium at 1 ppm concentration of solid in sea water was at equilibrium while at 100 ppm level showed a rapid uptake of almost all the cadmium in solution followed by a rapid release after two days. Lead, on the other hand, showed steady increase in concentration over time. Further study is being pursued with high mercury sediment. *(Contact: C.S. Wong.)*

Ocean Ecology

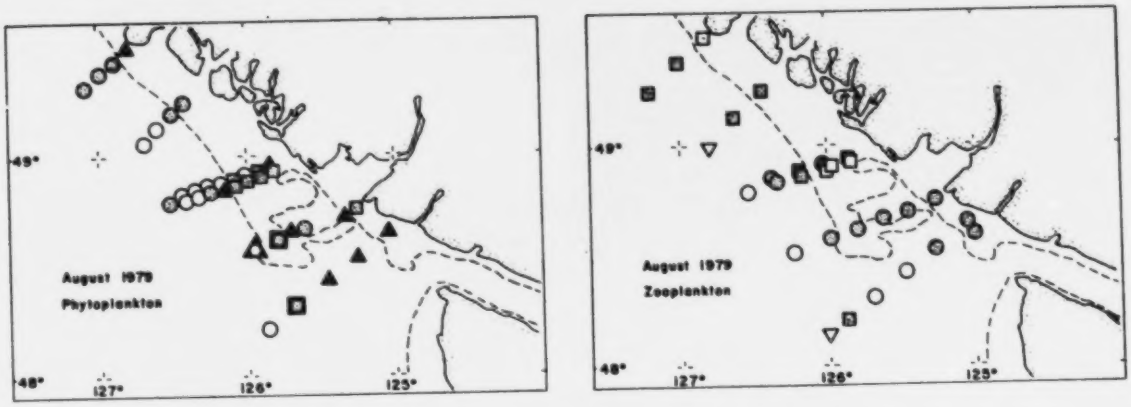
Plankton

Analysis of data from a four-year field program off the southwest coast of Vancouver Island revealed a planktonic ecosystem that is highly productive throughout the spring and summer. The nutrients that fuel this production flow up the Juan de Fuca submarine canyon system to the surface waters at the centre of the continental shelf from deeper offshore waters. This upward flow is caused by a counter-clockwise circulation above the canyons. Mathematical and statistical techniques were developed which allow the integration and comparison of physical data, continuous measurements of biomass, and discrete counts of species abundance levels by analysis of the spatial patterns. *(Contact: K. Denman, D. Mackas.)*





Distributions of surface (upper 5 m average) of temperature and depth-integrated (upper 50 m) phytoplankton biomass (estimated as chlorophyll concentration) off the southern B.C. coast. Contours are based on "objective mapping" from vertical profiles at the stations shown as dots.



Community composition of phytoplankton and zooplankton for the same time period shown in preceding figures. Symbols indicate station groups identified as having similar species dominance hierarchy by multivariate cluster analysis.

Similar techniques were used to study the small-scale zooplankton community pattern in the Alice Arm/Observatory Inlet system. Results to date suggest a differing compositional hierarchy near the head of Alice Arm. The difference is small, however, compared to the range of temporal variation. Laboratory studies using video monitoring equipment were undertaken to measure activity levels of zooplankton close by and away from the Amax mine outfall in Alice Arm. Findings will be published in 1983. *(Contact: D. Mackas.)*

Work on fine-scale (less than one kilometre) zooplankton pattern continued in Georgia Strait near the freshwater plume of the Fraser River. Papers were published on the signal resolution of flow-through pumping systems and on the potential impact of new plankton sampling developments on fish larval ecology. *(Contact: D. Mackas.)*

Studies of the influence of physical processes on the planktonic production continued. A theoretical study on the effects of vertical movement and light variation on primary productivity was completed. Another, on the numerical simulation of horizontal turbulence and phytoplankton patchiness, was initiated. New methods and equipment were developed to study the effects of variable light fields on phytoplankton productivity. One such system is a computer-controlled turbidostat which keeps the turbidity in the culture vessel at a constant level and thus maintains a constant phytoplankton concentration. *(Contact: K. Denman, S. Hill, R. Forbes.)*

Since the plankton sampling program using ships-of-opportunity was disrupted due to a prolonged tie-up as a result of the economic recession, IOS research cruises were used, on an as-available basis. This allowed a more varied spatial coverage but at the expense of repeated sampling along the same line. *(Contact: D. Mackas.)*

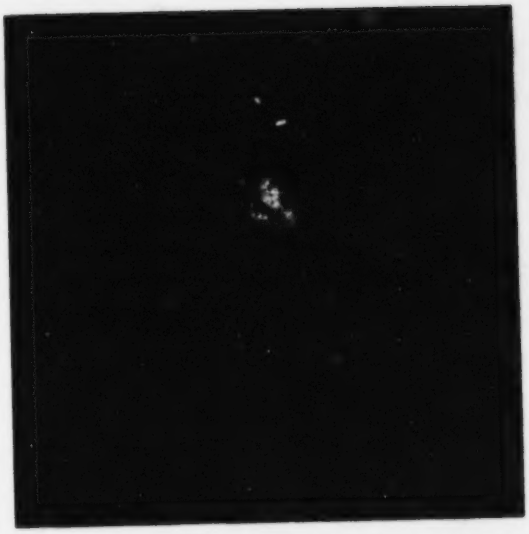
A copepod manual for B.C. waters was completed under contract and has been reviewed. The work will appear as a Fisheries and Aquatic Sciences Special Publication.

Benthos

The initial results are encouraging from the almost complete continental shelf benthos project which is being done under contract. Identifications of the major phyla and the dominant species from other phyla have been completed, and biomass estimates are now being made. Initial statistical analyses show that computer programs are functioning well.

Work on aquatic oligochaetes in 1982 included publication of a theoretical study of evolution in annelids. This material was also presented to the Second International Symposium in Pallanza, Italy. Progress was made on an update of a world taxonomic monograph produced a decade ago, and on descriptions or revisions of various taxa. In 1982 there was also considerable time spent in the provision of advice to consulting and industrial concerns around the world. Field and laboratory work on the squat lobster *Munida* in Saanich Inlet demonstrated good correlation. The largest animals have the lowest respiration rate and the largest gill mass and are found closest to the anoxic zone in the field. These animals migrate up and down the fjord walls just ahead of shifts in the level of deoxygenated water. In fjords without an anoxic zone, the animals are present at all depths and there is no size or gill mass difference in populations from various depths. *(Contact: R.O. Brinkhurst, H.R. Baker, K. Coates, B. Burd.)*

Corals and anemone. Cobb Seamount (375 m depth).



King crab on an inactive hydrothermal vent site.
Brown Bear Seamount (700 m depth).

Rockfish in a sea of brittle-stars.
Brown Bear Seamount (490 m depth).

A long-term monitoring project to establish the effect of mine tailings on sea-bed life was initiated. Samples were taken from the main basins of Alice Arm and Hastings Arm, well beyond the effluent outfall, and are now being analyzed.

The deep-water benthic program was expanded in 1982 with continued *in situ* investigations of rocky-bottom communities using the submersible, *Pisces IV*. During two autumn cruises, the faunas of several fjords were examined. An unusual assemblage of brachiopods and black coral was discovered in the Queen Charlotte Sound fjords, as well as numerous new species and new records of invertebrates. Collaborators include: Drs. W. Austin (Khoyatan Marine Laboratory), G. Mackie (University of Victoria), B. Gulliksen (University of Tromsö, Norway), and H. Reiswig (McGill University).

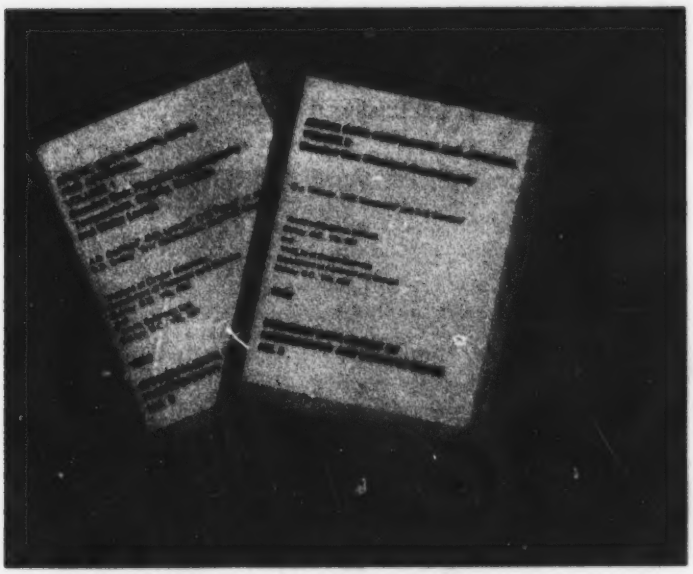
During August and September, two cruises to Cobb and Brown Bear Seamounts, 500 km offshore, were conducted to detail shallow-water animal assemblages and their relationships to young, volcanic substrata. Biologists and geologists from the University of Glasgow, University of British Columbia and University of Washington combined their efforts to study this area of continuing geological activity. The discovery of hydrothermal vents at this site will stimulate future investigations.

Ocean Information

Ocean Information Division activities support the management and exploitation of marine resources. Primary responsibilities include the collection and dissemination of oceanographic research data, the conduct of marine climatological analyses, the evaluation of environmental reviews, and the provision of information and advice through various committees to regulatory agencies. The Division also oversees the regional ocean dumping research program, provides information to the public, media relations, and policy and planning support for regional operations.

Oceanographic Data and Climatological Services

During 1982 a joint government/industry program to catalogue physical, chemical and biological oceanographic data sets was continued. Appraisal of data set quality has been a major component of the project to establish both the usefulness of the data and the priorities for archiving.



Hard copy volumes of Arctic Data Compilation and Appraisal; access is also available through IOS computer.

Arctic data set compilation and appraisal focussed on the Beaufort Sea and N.W. Passage — critical areas for offshore hydrocarbon development and transportation respectively, and the subject of an intensive Environmental Impact Statement (EIS) prepared by the oil and gas industry. The first volume, dealing with physical oceanographic data sets for the Beaufort Sea, was published in November 1982, and

will be followed shortly by similar volumes for the N.W. Passage, Queen Elizabeth Islands and Baffin Bay/Ellesmere island. Data-set catalogues covering chemical oceanography for the Beaufort Sea and N.W. Passage and benthos, plankton, fish and whale inventories for the Beaufort Sea have also progressed well and will be published in 1983. *(Contact: A. Cornford, B. Smiley.)*

The cataloguing of chemical oceanographic data sets — a companion study to physical oceanographic data sets completed at IOS in 1980 covering Queen Charlotte Sound/Hecate Strait/Dixon Entrance — is well underway, as is compilation and review of west coast marine environmental assessment and data reports. *(Contact: A. Cornford, L. Giovando.)*

A project to assist with marine aspects of the west coast Coastal Zone Folio mapping program has been initiated with DOE's Lands Directorate.

The B.C. Shorestation Oceanographic Program (lighthouse monitoring program) continued to supply surface seawater temperature and salinity data from 19 locations. In 1981, marked positive anomalies in surface temperatures occurred at shorestations exposed to the open Pacific Ocean (e.g. Langara Island and Amphitrite Point). The geographical drift of the peak of the anomaly suggested a northward-propagating event moving up the outer B.C. coast at about 7 km/day. However, preliminary examination of the 1982 data indicates that in the past year no such event occurred and suggests that, in general, coastal surface-water conditions were closer to those of the more "normal" year 1980. *(Contact: L. Giovando.)*

Initial steps were taken to assess a U.S. experimental fisheries-aid program for possible Canadian application. The joint Jet Propulsion Lab — NOAA (NWS) program was designed to provide reliable environmental information for fishermen, with the help of satellite observations. Specialized techniques to improve the analysis and forecasts of ocean-surface features (i.e. winds, waves, sea-surface temperatures, and colour boundaries) may be advantageous to commercial fishing operations. *(Contact: A. Cornford.)*

Environmental Services

Assessment of historical data sets especially those concerning chemical mass balances and budgets, mobility of wastes, and physical forcing affecting ice movement and oil spills was undertaken to prepare for government review of the oil and gas industry EIS for development in the Beaufort Sea and Mackenzie Delta. Considerable IOS effort was directed to appraising the adequacy of industry's environmental assessment for Arctic offshore hydrocarbon development. *(Contact: B. Smiley.)*

Environmental review activities continued in 1982 with participation in several phases of EARP (Environmental Assessment and Review Process) and various standing committees: RODAC (West Coast and Arctic Regional Ocean Dumping Advisory Committees), AWAC (Arctic Waters Advisory Committee), ARCOD and WESTCOD (Arctic and West Coast Offshore Development Committees). Items examined in 1982 included proposals for an LNG terminal in the Prince Rupert area,

an Initial Environmental Evaluation (IEE) by Petro Canada regarding Dixon Entrance/Hecate Strait, a proposal by Gulf for an Arctic shore base at Stokes Point and an environmental review of offshore oil and gas leases for COGLA (Canadian Oil and Gas Lands Administration). *(Contact: B. Smiley, L. Giovando.)*

Ocean Dumping

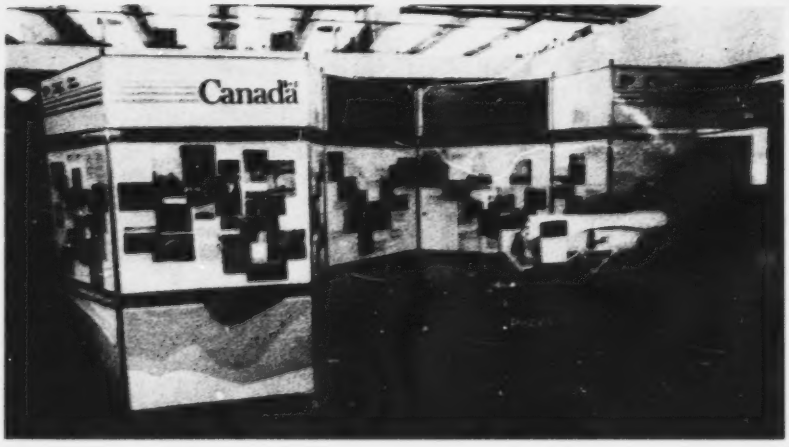
IOS maintains responsibility for the administration of the Ocean Dumping Control Act research fund for both Pacific waters and the western Arctic. Research results are available in the proceedings of the annual workshop. The Institute also serves in an advisory capacity regarding marine dredging and dumping permits issued by DOE's Environmental Protection Service (EPS). *(Contact: L. Giovando.)*

Information and Media Relations

IOS media relations and information activities increased with the arrival of a full-time information officer. Initial efforts involved the production of the Institute's annual review of activities, participation in the B.C. Science Fair and trade shows, and the preparation of material for publications concerning marine science, Arctic activities, and hydrography. *(Contact: K. Glover.)*

Policy/Program Analysis

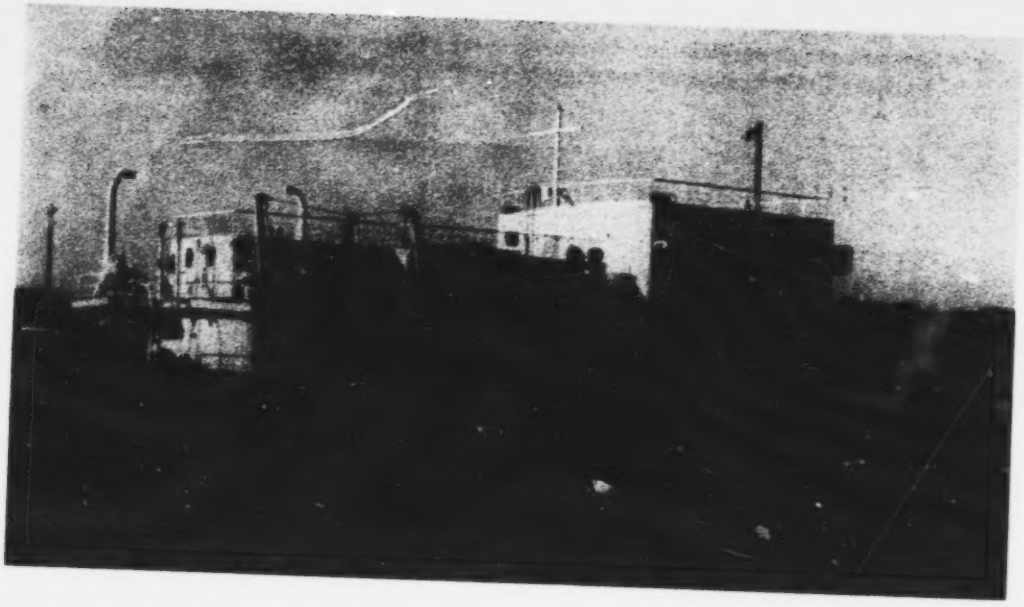
A well-documented Program Review and Evaluation (PRE) of research and survey activities was completed by senior staff, as was an updated Multiyear Operational Plan (MYOP). Several major program analyses were also undertaken. For example, reviews of ship utilization, Arctic oil and gas programs, and other energy-related programs were completed in conjunction with contributions to departmental Main Estimates and the Improvement of Management Practices (IMPAC) exercises. *(Contact: A. Cornford.)*



IOS display at B.C. Discovery Fair

Ships

CSS Vector



Barge Pender

The Pacific Region Ship Division provided ship, submersible, launch and depot support for the 1982 scientific programs of the Institute of Ocean Sciences, universities and other federal agencies.

CSS *PARIZEAU* (64.3 m overall; 1929 tonnes)
Master (Acting): B.L. Newton *Chief Engineer:* P. Pereira

CSS Parizeau was employed in support of scientific programs involving Field Hydrography, Tides and Currents, Ocean Chemistry, Ocean Ecology and Ocean Physics. The *Parizeau* also provided support for Pacific Geoscience Centre (PGC) and the Department of National Defence's Ocean Acoustics section. As well, *Parizeau* participated as a primary Search and Rescue (SAR) vessel for the herring roe fishing season.

During the winter *Parizeau* has been undergoing her mid-life refit and will be out of service for approximately three months. Major replacements include main engines, generators and ancillary equipment. Considerable changes are being made to the accommodation and structure. The ship's electronic capabilities are also being extensively updated.

CSS *VECTOR* (39.6 m; 505 tonnes)
Master: K. Sjoholm *Chief Engineer:* R. Pearson

CSS *Vector* carried out duties in support of Institute programs in Ocean Ecology, Coastal Zone Oceanography and Ocean Chemistry. Other agencies assisted included the University of British Columbia, Pacific Geoscience Centre, Simon Fraser University and the Environmental Protection Service (EPS).

CSS *RICHARDSON* (19.8 m; 78 tonnes)
Master: R.W. MacKenzie

The *Richardson* was used mainly by the Hydrographic Division in the field surveys in the Queen Charlotte Islands and northern Vancouver Island after an initial period with Search and Rescue.

M.V. PANDORA II, on charter (58.2 m; 1220 tonnes)
Master: R.A. Jones *Chief Engineer:* W. Weston

The *Pandora II* carried out Institute programs with Ocean Ecology and provided support for the University of Victoria, DND, B.C. Provincial Museum, Simon Fraser University, EPS and the Pacific Geoscience Centre. Many of these programs were in conjunction with the submersible *PISCES IV*.

PISCES IV (6.1 m; 12 tonnes)
Chief Pilot: F. Chambers

Pisces IV, having completed her first ten years of operations and recorded 1096 dives, entered into her mid-life refit. This was divided into two periods. Phase I took place between January 3 and July 4, 1982. During this period the *Pisces IV* was completely dismantled, repaired, modified, re-assembled and recertified to 700 metres. The major portion of Phase I work was carried out by *Pisces IV* staff with engineering support provided by Witney-MacInnis Engineering Ltd. The remaining work was contracted out to private industry. Phase II of the refit, scheduled for mid-January to mid-February 1983, will see the *Pisces IV* certified to 2000 metres.

Since the completion of Phase I, the *Pisces IV* in conjunction with the mothership *Pandora II,* has completed over 110 operational dives in support of Ocean Ecology programs and those of B.C. Provincial Museum, DND, University of Victoria, Pacific Biological Research Station and Pacific Geoscience Centre.

Barge *PENDER*

The barge *Pender* was used extensively by the Hydrography Division as a base for the field survey party that operated in the Seymour Inlet and Quatsino Sound areas from May 3 to October 8, 1982. The barge provided accommodation, support and maintenance facilities. On her return to Pat Bay the *Pender* was used locally by Coastal Zone Oceanography and Engineering Services.

Institute Workshops

In addition to the normal maintenance of the Institute's fleet of over 30 launches and tenders, the workshop undertook major rebuilds of four gas, four diesel and eight outboard motors of various sizes.

The launch *Nucleus* was completely gutted, and rebuilt and re-engined as a workboat at the beginning of the year and spent a successful season in support of the barge *Pender.*

The new twenty-nine (29) foot aluminum survey launches acquired this year, the *Wind* and the *Wave,* were fitted out, field tested and painted. Two more launches of this type are to be purchased shortly.

The shops were also heavily involved in special fabrication projects for various Institute divisions and lent support to the *Parizeau, Vector, Richardson* and barge *Pender.*

Deck Machinery

Deck Machinery continued to supply equipment and services for the scientific programs of the Institute, the Bedford Institute of Oceanography, Department of National Defence as well as to non-government users. All deck machinery from the CSS *Parizeau* is to be extensively overhauled during her mid-life refit.

Management Ser

Management Services continued in 1982 to provide the core support services for running the region and the Institute. These include: purchasing and materiel management, financial management, records management, communications, library services, and the operation and maintenance of buildings and grounds.

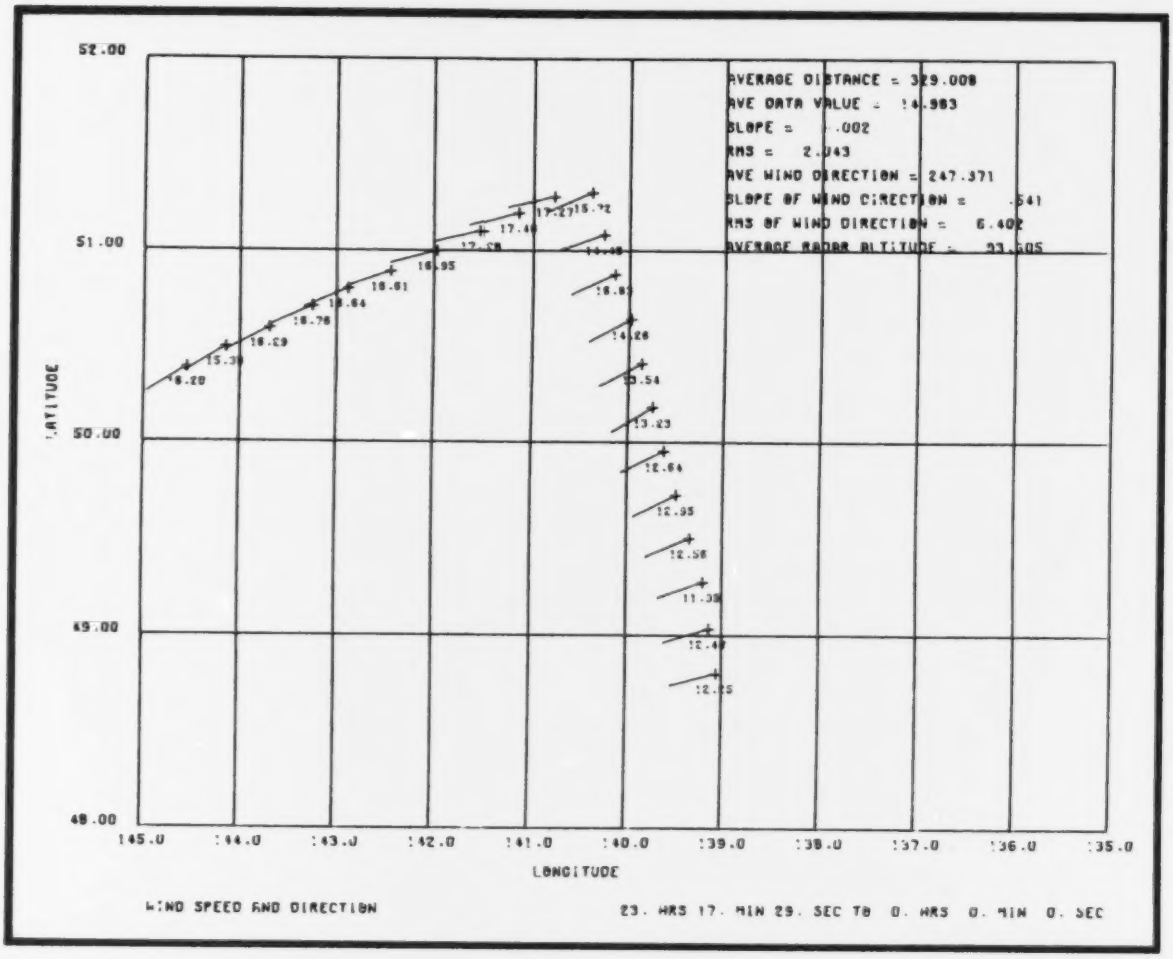
Some of the noteworthy events in 1982 included the enhancement of word processing capabilities. The region now has five stand-alone systems. These were installed after completion of an extensive study of regional needs. The telephone and other communication systems were rationalized to provide more cost-effective service.

Continued emphasis was placed on the federal government's energy conservation program. Two vehicles are now fueled by propane and two more are on order. Contracts were awarded for double glazing the main building using a new add-a-pane system. Fuel savings will recover installation costs in about six years. Studies were also carried out to improve the energy performance of the 40-year-old hangar. It is expected that the improvements will be made in 1983. The job of reroofing the hangar, including the addition of insulation, was started.

Library services operated at a satisfactory level. Development of systems and techniques using improved communication and computerized data bases continued, particularly on the departmental WAVES system.

A joint regional Ocean Sciences-Fisheries Management working group was formed to study and design improved purchasing, financial and distribution accounting systems using state-of-the-art technology for increasing productivity, processing time and for providing better control.

DEPARTMENT OF THE ENVIRONMENT



Measurements of wind from aircraft, using sensitive inertial navigation systems, can be used to provide detailed information on wind variability over the ocean. The lines indicate wind direction; the numbers give the speed in m/s.

Atmospheric Environment Service

Atmosphere - Ocean Interaction

During the Storm Transfer and Response Experiment (STREX) aircraft measurements of mean and turbulent meteorological parameters were made along "L" shaped tracks at several levels within the lower troposphere. From the mean data, after correcting for variations in the aircraft elevation along the track, it is possible to compute the geostrophic and thermal winds (theoretical winds due to pressure and density fields). These have been related to the vertical turbulent fluxes and the profiles of actual winds to aid in understanding and modelling atmospheric boundary-layer structure. During the STREX, simultaneous tracking of upper-air balloons was done by the NAVAID and radar windfinding systems. It was found that the two systems agreed well within the accuracies of either system. Since the NAVAID system is now being used on a volunteer observing ship between North America and Japan it was important to establish the relative accuracy of the system.

Three years ago, it was proposed at an international meeting that a large cooperative experiment be conducted to simultaneously estimate the meridional oceanic heat transport by three different techniques. The experiment, called Cage (because the techniques referred to used a measurement box or cage around the ocean basin), was to be done in the North Atlantic and/or North Pacific Oceans. An international study team, under the chairmanship of Dr. McBean and including Dr. A. Bennett, examined its feasibility and has recommended that it not be done because the probability of success was too small and that instead a coordination of ongoing or proposed programs be undertaken. *(Contact: G.A. McBean.)*

Precipitation Chemistry on the Pacific Coast

In order to ascertain the influence of industrial processes and urban areas on the chemistry of precipitation (principally the acidity), it is necessary to know the chemical composition in areas away from anthropogenic effects. A three-pronged measurement program has been started. Rain samples are collected at IOS. Rain samples are also collected on IOS cruises to Station P and to other areas. Snow samples have been collected at Mt. Washington and a helicopter survey to obtain snow cores in coastal mountains was undertaken. Through these data collection programs it it intended to determine the background marine chemical composition of rain/snow and to establish the representativeness of point measurements. *(Contact: G.A. McBean.)*

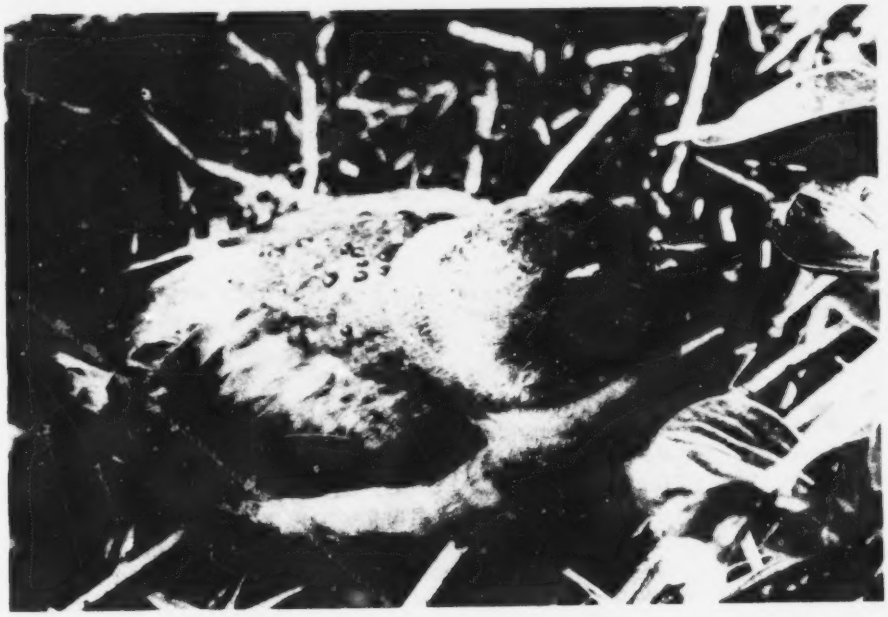
Splendor Mountain Lake—digging the pit.

Canadian Wildlife Service □□□

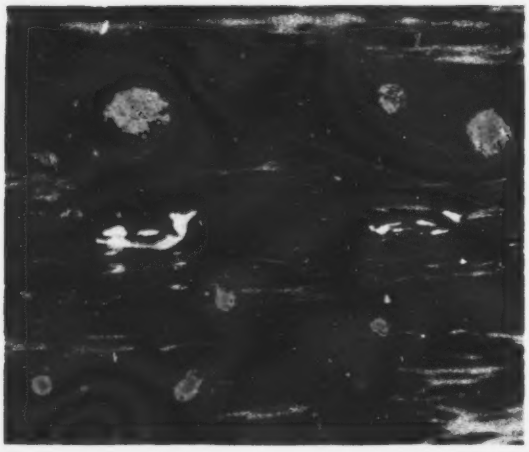
During 1982 work continued on preparation of an atlas showing the distribution and density of Canadian west coast bird populations. Publication is expected in early 1983.

Investigations of the Queen Charlotte Island archipelago seabird populations, conducted in 1982, will be continued in 1983. About one million seabirds nest in the Queen Charlotte Islands. Two species, the Ancient Murrelet and the Cassin's Auklet make up 77 percent of the seabird population there. Both species are small alcids and feed on zooplankton and larval fishes. The feeding strategies of the two alcids differ completely from one another. During breeding, the Cassin's Auklet acquires a throat pouch in which it brings food to its single chick in a nesting burrow at night. The chick is fed by the parents until seven weeks old, when it fledges and leaves the burrow for the sea. Unlike Cassin's Auklets, Ancient Murrelets do not develop a throat pouch and do not feed their young, but raise two chicks instead of one, and lead their two-day old and precocial chicks during darkness from their nesting burrow to the food source at sea. At sea, the parents remain with their chicks until they fledge.

Cassin's Auklet on the breeding ground.



Two-day old Ancient Murrelet chicks.



A pair of Ancient Murrelets.

The distribution of the two species on the nesting grounds as well as on the feeding areas at sea, will be investigated for the next few summers to determine the birds' requirements. Preliminary findings indicate that the Ancient Murrelets prefer to nest beneath mature canopies of Sitka spruce and western hemlock where undergrowth is scarce. Clearcut logging as practised in the Queen Charlotte Islands may destroy suitable Ancient Murrelet nesting habitat. Ancient Murrelets have not been found nesting in logging slash or regenerated forests. On the feeding areas at sea, both Ancient Murrelets and Cassin's Auklets may be vulnerable to potential oil spills from tankers between Alaska and Washington State, as well as to potential blowouts and leakages from drilling activities that are proposed offshore from the Queen Charlotte Islands. To determine the vulnerability of the small alcids to oil spillage, the Canadian Wildlife Service (CWS) will examine their distribution at sea. *(Contact: K. Vermeer.)*

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Pacific Geoscience Centre

Pacific Geoscience Centre at IOS.

Earth Physics Branch and Geological Survey of Canada

Foreword

The purpose of the earth science programs within the Pacific Geoscience Centre is to collect geological and geophysical information on the evolution, the structure and the dynamic processes of the solid earth and the hazards associated with natural and induced geological processes. The western Canadian landmass and offshore regions are preferentially studied.

The projects described on the following pages have provided data for a number of aspects of these broad objectives. In particular, marine programs have provided data for the development and extension of ideas about contemporary and past plate motions along the western continental margin. These studies, coupled with expansions of the seismological network, levelling, and geodynamic surveys, are continually improving our understanding of earthquake mechanisms, frequency and risk. Systematic marine surveys in co-operation with the Hydrographic Service are also playing a vital part in providing a data base for the evolution and understanding of the mineral resources that may occur in Canada's western offshore areas.

Geothermal studies continued to explore and delineate alternative energy sources and to provide important scientific information about deep crustal structure. Gravity surveys in the Rocky Mountains continued as part of the long-term regional coverage of the northern Cordillera, now the principal remaining gap in the National Gravity Data set. Geological studies have been directed towards and understanding of the history of the rock formations along the margin and of the deposition, composition and stability of sediments on the continental shelf and in coastal inlets. These studies provide input both into resource evaluation and into assessments of the environmental impact of the wide range of construction and development projects occurring along the coast and of offshore petroleum exploration.

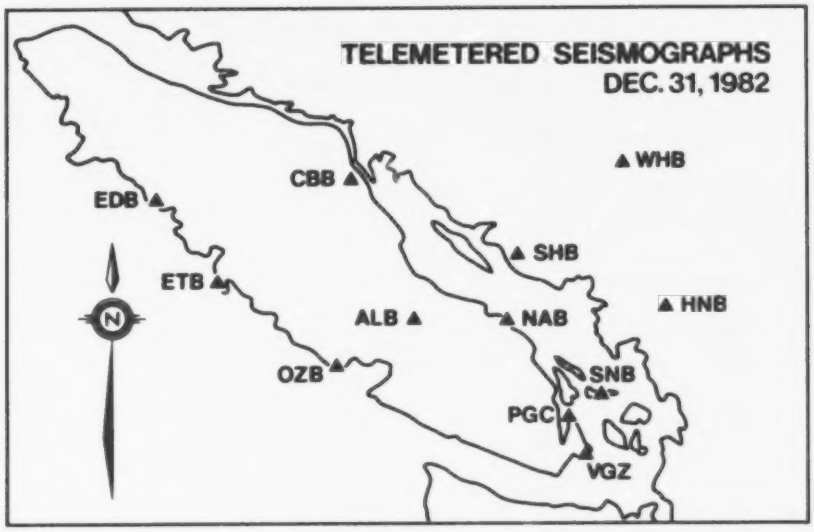
Seismological Service

The Seismological Service provides earth scientists, civil engineers, resource development industries and the public with basic earthquake data, and with research information concerning natural and induced earthquakes, ground motion, seismic risk, earth structure, and nuclear explosions. This is accomplished through a

network of seismological stations, including standard and regional stations, two telemetered arrays, strong motion accelerographs, and special installations.

Seismic Networks

The Western Canada Telemetered Network (WCTN), established to provide centralized, on-line monitoring of seismicity in southwestern British Columbia, was expanded in 1982 by three stations along the west coast of Vancouver Island and one station at the Gonzales Observatory in Victoria. Twelve stations were being recorded at the Pacific Geoscience Centre (PGC) by the end of the year. Preparatory site work was also completed for an additional site near Port Renfrew. The network located almost 200 small earthquakes in the Vancouver Island – Strait of Georgia region in 1982. *(Contact: D.H. Weichert, G.C. Rogers, M. Bone, A. Whitford.)*



The West Coast Telemetered Network (WCTN) for earthquake monitoring currently comprises 12 seismic stations whose signals are transmitted to a central computer at PGC. Automatic monitoring of these signals permits virtually on-line location of seismic events in southwest British Columbia.

The strong motion seismograph network in western Canada, which consists of instruments designed to operate and record ground acceleration only when very strong (½% of normal gravity or larger) earth motion occurs, remained at 33 accelerographs, although some site changes were made. During 1982, PGC personnel coordinated the reduction and the publication of the strong motion records from the New Brunswick earthquakes. *(Contact: D.H. Weichert, H. Bennetts.)*

Staff at the Pacific Geoscience Centre updated catalogues to provide the time and location of earthquakes occurring in western Canada. For the first half of 1982, about 300 earthquakes have been added to the catalogue. *(Contact: R. Horner.)*

Special Earthquake Studies

The separate cooperative projects with Dome Petroleum Ltd. and B.C. Hydro and Power Authority, in order to monitor earthquake activity for local seismic risk estimates in the Beaufort Sea region and in northern British Columbia, continued in 1982. The seismograph records are sent to PGC for analysis. *(Contact: D.H. Weichert; G.C. Rogers.)*

Three new regional seismic stations were commissioned in Ocean Falls, Cape St. James and in Tasu, to improve the coverage of the Queen Charlotte Island area. *(Contact: D.H. Weichert.)*

Revision of the epicentres of earthquakes occurring in the Queen Charlotte Islands region has been done. Almost all earthquakes have epicentres close to the Queen Charlotte fault with no evidence that significant earthquakes have occurred in Hecate Strait or Queen Charlotte Sound in historic time. The revised seismicity pattern plus microearthquake observations on the Queen Charlotte Islands suggest that there is little seismicity on other major fault systems to the east of the Queen Charlotte fault. During 1982 only one magnitude 3½ event occurred on the east side of Hecate Strait and one magnitude 4 event occurred on the fault near Masset, Queen Charlotte Islands.

The focal mechanisms of earthquakes along the Queen Charlotte fault suggest the fault is not a pure transform at its southern end but has an element of convergence across it.

The distribution of large earthquakes and their aftershocks along the Queen Charlotte fault indicate the existence of a seismic gap just south of the Queen Charlotte Islands which would require an earthquake the order of magnitude 7 to fill it. *(Contact: G.C. Rogers.)*

A microseismicity study in the St. Elias region has been completed. The most active zone of seismicity follows the Pacific-America plate boundary along the coast of Alaska. A less active zone follows the Denali fault system through the southwest Yukon, but it does not continue into Chatham Strait. Instead, it turns south into the Glacier Bay region to connect with the Fairweather fault. *(Contact: R.B. Horner.)*

Seven strong motion recorders were installed in the epicentral area of the 1982 New Brunswick earthquake series. Twelve records were obtained. Peak ground acceleration ranged from a few percent to many tens percent of the gravitational acceleration constant. Dominant frequencies of the records are high (25 Hz and more) so that ground velocities are only a few cm/s. consistent with the observed intensities. *(Contact: D.H. Weichert.)*

A synthesis of seismic refraction and multi-channel reflection data from the Winona sedimentary basin off northern Vancouver Island has demonstrated that Pleistocene turbidite sediments have seismic velocities in excess of 5 km s^{-1}. Extremely rapid de-watering and diagensis can explain these unusual velocities. *(Contact: E.E. Davis.)*

A compilation of magnetic, bathymetric, photographic, seismic reflection and dredged sample data has revealed the nature of the propagating offset on the Juan de Fuca Ridge at 47°30'N. The ridge is currently spreading along a continuous curved centre, which connects the northern and southern straight ridge segments. *(Contact: E.E. Davis.)*

Seismic Risk Estimation

The Pacific Geoscience Centre provides site specific risk estimates for many engineering projects in western Canada. New risk maps were completed in 1982, which will be incorporated in the 1985 National Building Code of Canada. *(Contact: D.H. Weichert.)*

Geothermal Studies

The earth's temperature influences both rock properties and geological processes. Thermal data, particularly surface heat flux, are among the most important indicators of deep tectonic processes and the structure of the earth's crust. Most active tectonic processes that result in mountain building, earthquakes and volcanism originate from thermal energy. In addition, the earth has considerable economic potential as a heat source for geothermal energy.

Measured thermal parameters include surface heat flux (the result of vertical temperature gradient multiplied by the thermal conductivity of the rocks), and heat production from natural radioactive decay in crustal rocks (for example: thorium and potassium). Studies cover a wide range of geological and geophysical interests — from heat flow, heat production and thermal processes in the deep sea floor, to the discovery and development of geothermal energy resources in western Canada.

Land Studies

There is a continuing program to determine the regional geothermal heat flow pattern from borehole measurements in the Canadian Cordillera. These data can be used in the interpretation of regional tectonics and structure, and in the delineation of hot areas with potential for geothermal energy development. In south central British Columbia, the heat flow measured in shallow holes along a 200 km profile

across the Okanagan Highlands is remarkably uniform at 75 mW m^{-2}. Measurements are being completed in additional shallow holes in the Garibaldi and the Alert Bay Volcanic Belts. *(Contact: E.E. Davis, T.J. Lewis.)*

A gamma-ray spectrometer is used to measure the heat generation in samples of rock. A new PDP-11/23 computer was interfaced to the 7010 EG & G spectrometer and several hundred samples were measured. The mine tailings from the Amax mine in Alice Arm have less radioactivity than many normal surface rocks, including the outcrops sampled on Alice Arm. The average heat generation of Scotian Shelf sediments cause the temperture at the bottom of the basement to be 17°C higher than if there were no heat generated within the basin.

Marine Studies

A series of repeat marine-probe, heat-flow measurements have been carried out up the length of Jervis Inlet to investigate further the previously observed increase of heat flow as the Garibaldi Volcanic Belt is approached. The large increase in heat flux by a factor of two is observed to take place near the head of the Inlet over a distance of 20 km. The bottom sediments of Bute Inlet were found to be too hard to penetrate with long oceanographic heat-flow probes. *(Contact: T.J. Lewis.)*

Further northward in Queen Charlotte Sound, a suite of cores and heat-flow measurements have shown that coarse-grained and over-consolidated sediments are pervasive as a result of Holocene non-deposition and submarine erosion. Variations of bottom water temperature preclude the measurement of reliable heat flow with penetrations of only 9 cm. *(Contact: E.E. Davis.)*

The thermal regime of the Queen Charlotte fault zone area and Queen Charlotte Basin was examined through ocean probe, petroleum-exploration well temperatures and thermal conductivity data. Thermal models were developed for an underthrusting oceanic lithosphere and a margin rift. *(Contact: R.D. Hyndman, T.J. Lewis, C.J. Yorath.)*

The heat flow and hydrothermal regime in a Deep Sea Drilling Project (DSDP) deep-ocean crustal borehole on the mid-Atlantic ridge has been examined. The heat flow measured in the deeper part of the hole is high, very close to the theoretical cooling lithosphere value.

A review of all heat flow measurements obtained in deep boreholes by the DSDP ship *Glomar Challenger* has been prepared. The study confirmed that shallow heat probe measurements generally provide nearly as reliable heat flow data as the deeper borehole measurements except near ridge crests. A compilation of all geothermal heat flow values offshore and onshore for the area covered by the Juan de Fuca Plate map sheet has also been completed. *(Contact: R.D. Hyndman.)*

An analysis of four suites of closely spaced heat flow sites in the Jurassic of Northwestern Atlantic has been done. The heat flow from lithosphere ranging in age from 110 to 155 Ma is uniform and high. Boundary-layer cooling or plate

cooling does not explain these results. A reheating of the lithosphere can account for the high heat flow values. *(Contact: E.E. Davis.)*

Gravity

The principal task of the Gravity service is to establish the shape of the geoid in Canada to the highest standards and to determine the value of gravity on a regional basis over the Canadian landmass and offshore areas. The geoid is the reference surface for all surveying and mapping. The regional gravity data provide information for both the determination of crustal structure and the evaluation of resources and are critical to the operation of inertial navigation systems used by defence agencies for submarines and missiles.

Seaborne operations in 1982 aboard CSS *Parizeau* covered an area of 35,000 km² on a systematic 10 km line spacing out to the 200 nautical mile limit southwest of the Queen Charlotte Islands. Two La Coste and Romberg dynamic gravimeters were operated simultaneously: SL1, the "linear" prototype meter tested in 1980 and a three-axis "beam" meter, S56. Comparison of the two systems again showed that the linear meter performed with greater accuracy. In particular, because of the reduction of cross-coupling due to ship movement, it was more tolerant of rough water.

The 1982 survey will be integrated with the continuing series of regional offshore surveys for release in 1983. Two extended lines of 400 km length were surveyed out to 137°W in an attempt to locate magnetic anomaly 6 (20 Ma old) and check the existence of a proposed "pseudo fracture zone".

Land regional gravity surveys by helicopter were completed in 1982 under contract in an area between Jasper and Prince George by Terra Surveys Ltd. As in previous years, a combination of existing monumentation and intertial navigation was used to provide the required ±50 m horizontal and ±3 m vertical control. Two hundred and eighty new stations were observed. *(Contact: R.P. Riddihough, D. Seemann.)*

Geodynamics

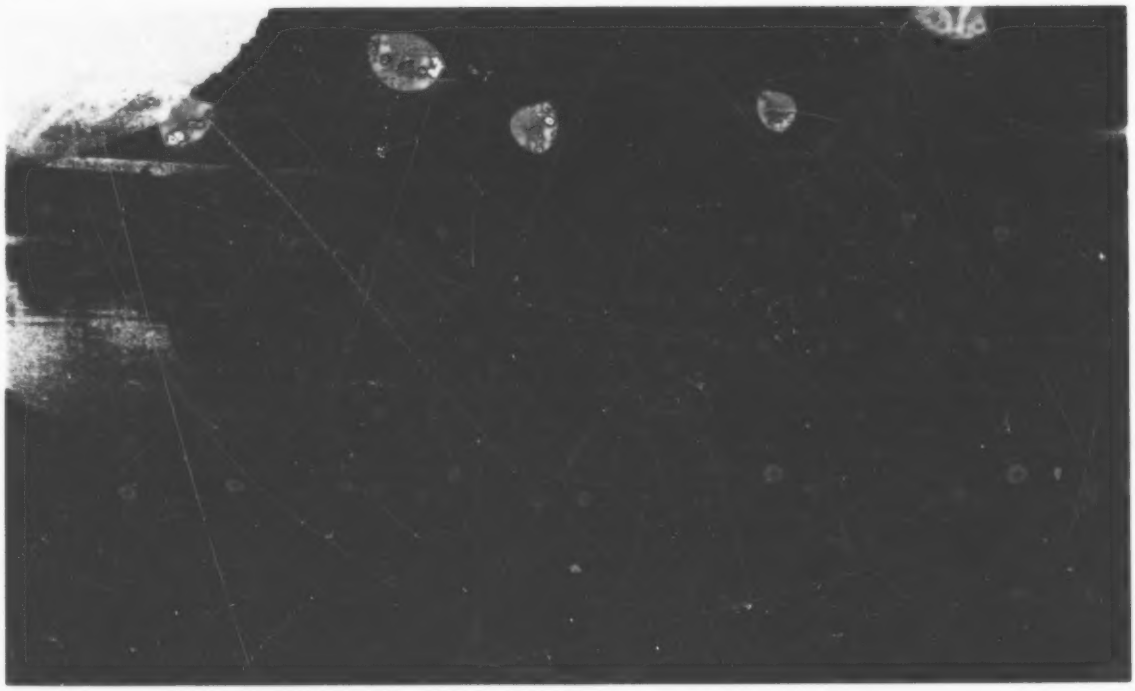
The principal subject of study for geodynamics in the active tectonic regions of Canada's west coast is contemporary crustal deformation. One objective of this research is to establish realistic dynamic models of crustal plate behaviour and utilize these in the study of earthquakes.

Efforts to measure crustal strain continue to be concentrated in central Vancouver Island near the epicentral region of the 1946 earthquake. Precise gravity surveys and repeated vertical control surveys over the past year indicate irregular aseismic vertical deformation of the order of 1 cm/a accompanied by significant

local mass changes most likely due to groundwater injection or withdrawal in fracture zones.

A nine-station triangulation network established in 1947 in the Gold River area was resurveyed using laser-ranging instrumentation. Precisions of 3 parts in 10^7 were obtained over line-lengths of up to 40 km. Future resurveying of this network will provide a measurement of present-day horizontal crustal strain in this critical region which straddles the landward extension of the Nootka Fault zone.

Preparatory work for the measurement of relative crustal deformation over baselines of thousands of kilometers using VLBI (Very Long Baseline Interferometry) was continued. Reconnaissance for site locations for NASA's 4 m 'portable' radio antenna was carried out in Yellowknife, N.W.T., and in Whitehorse, Y.T. Local geodetic networks were established in each locale for future site stability measurements. The first horizontal control survey of the local geodetic network containing the proposed VLBI site at Penticton, B.C., was completed in August. *(Contact: H. Dragert.)*



The measurement of small changes in elevation over periods of a few years is extremely difficult especially in regions with limited road access. Using very sensitive gravimeters transported by helicopters or float-aircraft, vertical strain measurements can be carried out over long distances in the rugged terrain of Canada's west coast.

Geomagnetism

The Geomagnetic Field

The earth's geomagnetic field varies both spatially and temporally. This inherent variability of the geomagnetic field is exploited in a variety of ways. To be utilized for navigation, the magnetic field and its gradual change with time must be determined as a function of latitude and longitude. Changes in the magnetic properties of rocks also lead to spatial variations in the magnetic field which become characteristic signatures of structure, composition, and the thermal history of crustal rocks. Short-period temporal changes in the magnetic field must be monitored in order to resolve subtle spatial field variations as encountered in exploration geophysics.

In Canada, the geomagnetic field is monitored continuously at 13 primary observatory sites and discontinuously at about 140 secondary sites. As part of this Canadian Geomagnetic Network, the Pacific Geoscience Centre operates the Victoria Geomagnetic Observatory (VGO) on property near the Dominion Astrophysical Observatory.

The Pacific Geoscience Centre also collects magnetic field observations at the 15 repeat stations in British Columbia. These data are used in updating maps of the geomagnetic field components for the Canadian land mass every 5 years. During the summer of 1982, measurements were obtained at 2 of these sites.

Geomagnetic Variations

Temporal variations in the earth's magnetic field provide a source of electromagnetic energy with which to probe the earth's electrical conductivity structure. Zones of high conductivity, if related to high temperatures and partial melting, can be used to define areas of geothermal interest. Geomagnetic depth-sounding can also determine the thickness of the cold lithospheric plate riding over the asthenosphere, an important parameter in understanding the active tectonic regions dominant on the west coast.

Confirmation that the cold Juan de Fuca lithospheric plate does indeed dip beneath the continental mass under Vancouver Island has been derived from an analysis of the geomagnetic data obtained in a 1980 experiment. A finite difference approximation of Maxwell's equations for a model consisting of a descending lithosphere beneath Vancouver Island predicted quite closely P.G.C.'s observations across the continental margin.

Ocean bottom magnetometers (OBM) were recovered, after a 33 day recording period, from 3 sites across Queen Charlotte Sound to the abyssal plains west of the Sound. The vertical magnetic field recorded at the base of the slope was far greater than those at the shelf or the deep site. The enhancement of the vertical field may be due to the proximity of the site to the Queen Charlotte transform fault zone.

The injection of electric current into the sea floor via a vertical cable from a ship produces magnetic fields that can be measured with OBM's. At the Queen Charlotte Sound site, on the shelf (200 m depth), this procedure was further tested, with successful recordings of signals out to 10 times the vertical water depths. This result confirmed that a deep ocean (3 km say) experiment should give signals sufficient to probe the conductivity structure of the oceanic lithosphere (to 30 km).

In order to determine the conductivity structure beneath Vancouver Island more precisely, many samples of variations in the electromagnetic field components are required. In 1982, about 40 days of recordings were obtained at the two standard sites in central Vancouver Island. Repeated observations at these sites will be done in the future in order to monitor possible temporal changes in crustal conductivity structure. *(Contact: L. Law, J. DeLaurier, D. Auld.)*

Paleomagnetism

The paleomagnetism of rocks records the variations in directions of the geomagnetic field in the geological past. The intensity of the ancient field is also recorded but is more obscure and difficult to observe and can only be obtained in very favourable circumstances. The principal application of paleomagnetism is in tectonics — the study of the motion of continents, the opening and closing of oceans and the origin of mountain belts — but it is also used widely in many problems of stratigraphic correlation, the origins and thermal history of rocks, and in the source and origin of magnetic anomalies.

The paleomagnetic laboratory currently being installed at PGC included two microprocessor controlled spinner magnetometers used to measure the remenant magnetic fields in rock samples. The raw data are communicated directly to the mainframe computer for analysis.

The new paleomagnetic laboratory at PGC is nearly complete. Work will be related mainly to studies of the tectonics of the Cordillera and the western Arctic and to magnetostratigraphic studies. During the last decade, geological and geophysical studies have shown that the Cordillera comprises a number of distinct crustal blocks. Vancouver Island is one such block. Paleomagnetic work has shown that these blocks have been transported from the south by distances over 1000 km, much of central British Columbia once being in the latitude of California. Vancouver Island could have moved northward by over 5000 km relative to North America and may even have originated on the other side of the Pacific Ocean. The western Cordillera, therefore, appears to be a collage of small crustal fragments that originated elsewhere, were carried over large distances, and finally glued to North America. This discovery has led to a profound revision of our ideas about the origin of this and other mountain belts.

Two major programs were initiated. The objective of the first is to collect a suite for a traverse across the Cordillera from Vancouver Island to the Rockies in order to determine the relative latitudes of the various crustal elements at one geological instant in time; namely the Middle Cretaceous epoch near 100 Ma ago. The second program calls for a traverse across the northern rim of the Sverdrup Basin in Ellesmere Island. Results show an unexpected 30° anticlockwise rotation which may reflect strain distributed across northern Ellesmere Island and may be associated with the opening of Baffin Bay. *(Contact: E. Irving.)*

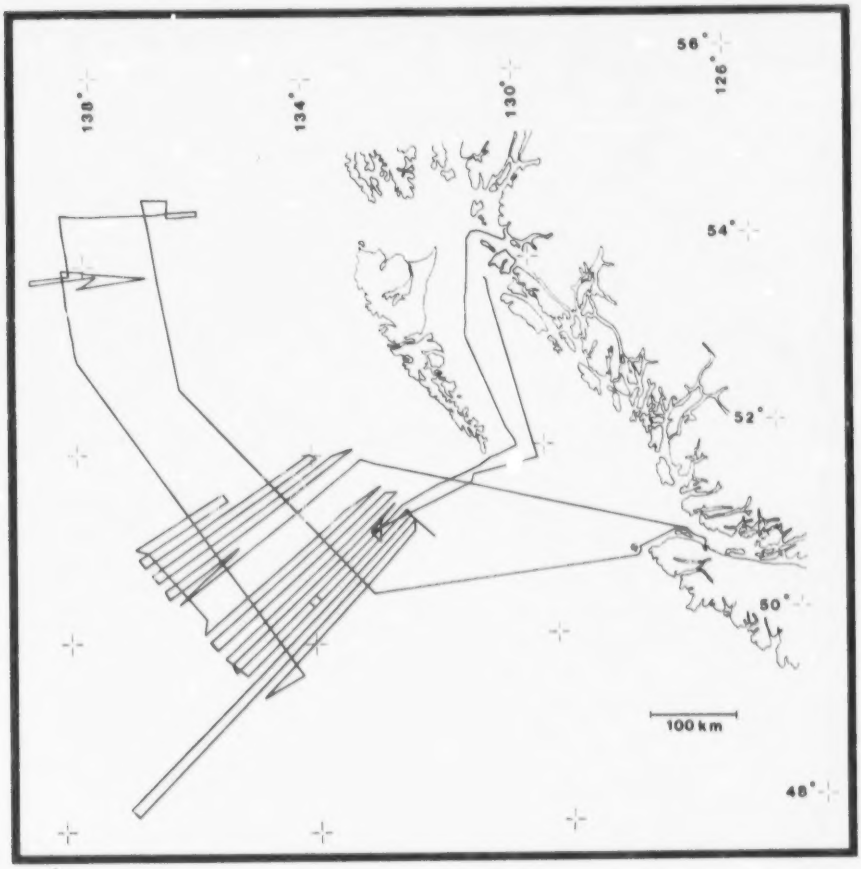
Arctic Tectonics

Two new ideas about Arctic tectonic history have been suggested. The first suggests that the mid-Paleozoic Ellesmerian orogeny in the Arctic Islands was produced when a continental terrane that included northern Alaska was displaced southwestwards by as much as 2000 km from its initial orogenic site to the north and east of Ellesmere Island. The second idea is that the Lomonosov Ridge was sheared from the polar margin of western Eurasia, probably in Late Cretaceous time, along a trans-Arctic left-lateral offset that may have been related to the opening of Baffin Bay. The Eurasia Basin was opened later, in early Tertiary time, when the North Atlantic rift extended into the Arctic region and separated the Lomonosov Ridge from Eurasia.

An Arctic volume contribution to the series "Geology of North America" has been specified and publication is expected in 1985. The editors have published a regional overview and have selected the contributors. The North American Continent — Ocean Transects Program consists of 23 margin studies in progress around the continent. One of these is in the Arctic; the cross-section sheets and the pertinent manuscripts are nearly completed for publication in 1984. *(Contact: J.F. Sweeney.)*

Geological - Geophysical Studies

Systematic magnetic, gravity and bathymetric surveys are being conducted over the Canadian Economic Zone to help assess the economic potential of the region and its tectonic framework. The 1982 survey in this Resource Mapping program was conducted between 180 and 360 km west of the Queen Charlotte Islands (approx. 50°N to 54°N). Continuous magnetic, gravity and bathymetyric data were collected in 770 km of survey and tie lines in this previously unsurveyed area of the northeast Pacific. The new magnetic data fills a gap between the *Pioneer* data to the south and early Pacific Geoscience Centre surveys to the north. In addition, a test line was run to approximately 550 km offshore in an attempt to place limits on the position of a propagating rift trace. *(Contact: R. Currie.)*



The ship's track lines for the 1982 Resource Mapping Survey west of Queen Charlotte Islands.

Geological studies on the Queen Charlotte Islands and concurrent geophysical programs in Hecate Strait and Queen Charlotte Sound have led to new interpretations of the tectonic history and petroleum potential of the Queen Charlotte Basin. The recognition of the origin and timing of collision of exotic crustal fragments and the rift origin of Queen Charlotte Sound has permitted new geophysical modelling of the dynamics and thermal history of the basin. Two possible sources of hydrocarbons are indicated. The first is related to the possible occurrence of petroliferous Upper Triassic and Jurassic rocks beneath southern Hecate Strait similar to those observed on the Queen Charlotte Islands. Rifting in Queen Charlotte Sound possibly has allowed these older hydrocarbons to migrate upward along faults to become trapped within the Tertiary sediments. The second source for hydrocarbons lies within the tertiary sediments themselves. The subsidence and thermal history of the basin suggest that sufficient metamorphism of organic matter would have occurred. If petroleum source rocks are eventually found, favourable reservoir rocks within the basin may contain liquid hydrocarbons of Tertiary age. *(Contact: C.J. Yorath).*

Paleontology

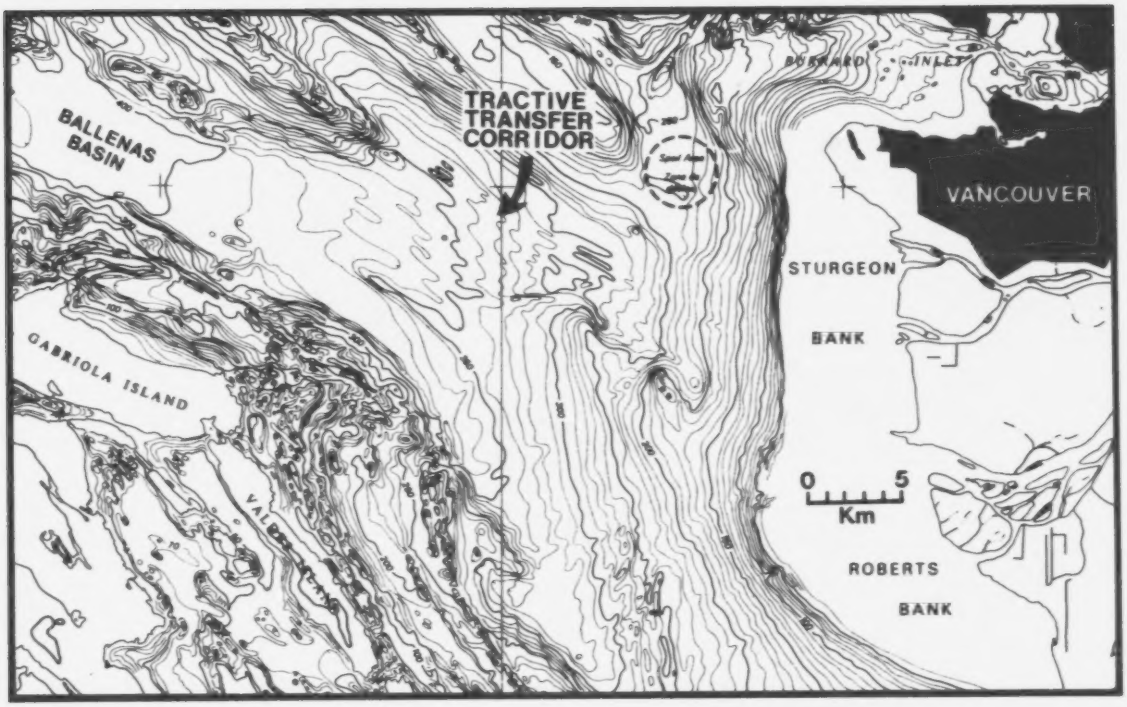
Activities in Paleontology at the Pacific Geoscience Centre are focussed on micropaleontological biostratigraphy of Mesozoic and Cenozoic rocks of the complex Pacific margin of Canada. Work is continuing in studies of Teritary biostratigraphy both on land and offshore with emphasis on depositional environments and planktonic foraminifers. Ultimately this study should assist in understanding the tectonic evolution of the west coast and its potential for oil and gas exploration. *(Contact: B. Cameron.)*

Sedimentology

Estuarine and Marine Delta Sedimentation

As in previous years demand has remained high for geological data from the Fraser River delta which can help formulate environmental/engineering guidelines. Results of geological research have been applied to investigations by outside agencies relating to the proposed Iona Island sewage pipeline, Westshore Terminals coalport expansion and B.C. Hydro proposed Vancouver Island gas pipeline.

Research has focused on defining the influence of deltaic processes on the adjacent Strait of Georgia seafloor and elucidating the major stages of Fraser River delta evolution. *(Contact: J.L. Luternauer.)*



The tractive transfer corridor has been identified as the major pathway for turbidity/density currents originating at the Sturgeon Bank (Fraser River Delta) slope. Contours in metres. (Base Map: Canadian Hydrographic Service Natural Resource Map 15792-A)

Coastal Studies

Coastal sedimentology and geomorphology are studied to (i) provide a data base for port location, industrial development, and shoreline management and recreation, (ii) develop oil spill contingency plans including an assessment of the fate and behaviour of oil in the coastal zone and cleanup techniques and, (iii) elucidate the geological evolution of British Columbia's coastline.

To achieve these aims, six locations throughout the Strait of Juan de Fuca, the Gulf Islands and the Strait of Georgia were chosen, each location containing a variety of environments representative of the coast. About 500 sediment samples were collected for sediment textural analysis which, when complete, will provide not only a description of each of the facies encountered in the beach and nearshore zones, but also the basis for understanding the sedimentary dynamics of the coastline. In addition to sampling, beaches and nearshore environments at each location were surveyed, the latter with both an echo sounder and a sub-bottom

profiler. A SCUBA program enabled first-hand observation of the submarine environments.

These surveys are used to develop a process-response model to describe the evolution of the beach nearshore system within the Strait of Georgia. The nearshore profile develops a characteristic shelf form. The width of the shelf and depth of water at the shelf break increase with exposure to wave energy. Statistical relationships between the wave climate, shelf morphology, and sediment distribution provide a model of the shelf as an equilibrium size-graded form, similar to prograding shelves on the continental margins. *(Contact: P. McLaren.)*

APPENDIX I

Contracts Awarded 1982/83

Depth Sounder Frequency Synthesizer
Analytic Systems Ware Ltd., Vancouver, B.C. . $ 1,672

Collection and Analysis of Alice Arm Zooplankton Samples
Edward Anderson Marine Sciences, Victoria, B.C. 19,000

Contract Monitoring System
Anthony Macauley Associates Ltd., Victoria, B.C. 8,150

To Study the Impact of a Lead-Zinc Mining Operation on the Marine Environment of Strathcona Sound, N.W.T.
Arctic Laboratories Ltd., Yellowknife, N.W.T. 1,500

Analysis of Surficial Marine Sediment
Arctic Laboratories Ltd., Sidney, B.C. 17,500

Study of the Long-term Mobility of Discharged Drilling Fluids in the Beaufort Sea
Arctic Laboratories Ltd., Sidney, B.C. 15,810

Preparation of Draft Report on Beaufort Sea Zoobenthos Data Compilation
Arctic Laboratories Ltd., Sidney, B.C. 6,418

Compilation and Appraisal of Existing Chemical Oceanographic Data in the Northwest Passage
Arctic Laboratories Ltd., Sidney, B.C. 39,705

Development of Computer Software Related to Data Inventory Studies of the Beaufort Sea, Northwest Passage and Arctic Islands
Arctic Sciences Ltd., Sidney, B.C. 9,421

Preparation and Reformat of Beaufort Sea Physical Oceanographic Data for Archiving
Arctic Sciences Ltd., Sidney, B.C. 25,624

Continuation of a Synoptic Aircraft-Based Oceanographic Survey in the Arctic Archipelago
Arctic Sciences Ltd., Sidney, B.C. 113,593

Development of Computer Software for Contouring Field Hydrographic Data
Barrodale Computing Services Ltd., Victoria, B.C. 171,150

Study of the Theory of Flow Over Sill
B.L. Blackford, North Saanich, B.C. 15,000

Identification and Enumeration of Zooplankton Samples
Broccoli Bros. Enterprises Inc., Sidney, B.C. 8,000

Ship of Opportunity Sampling of the Planktonic Ecosystem Off the Pacific Coast of Canada
Broccoli Bros. Enterprises Inc., Sidney, B.C. 51,603

Development of a Fibre Optic Interferometer with Applications to Sensors Communications and Laser Instrumentation
Canadian Instrument & Research Ltd. 272,794

The Sedimentation of Mine Tailings in a Marine Environment (Phase I)
Capital Applied Research (Retech), Victoria, B.C. 38,382

Development of a Methodology to Determine Bio-accumulation and Sub-lethal Toxicity into the Food Web of Ocean Dumped Material using a Polychaete Worm and a Benthic Flatfish
Dobrocky Seatech Ltd., Sidney, B.C. 86,901

Analysis and Interpretation of Oceanographic Data from Bridport Inlet, Melville Island, N.W.T.
Dobrocky Seatech Ltd., Sidney, B.C. 14,000

Boat Charter
J. Egeland Fish Co., Sooke, B.C. 46,360

Computer Software
Empirical Research Group Inc., Milton, Wn. 9,951

Assessment of Environmental Reviews and Data Reports for the West Coast and Beaufort Sea
Environmental Sciences Ltd., Vancouver, B.C. ... 10,000

Compilation, Review and Assessment of Major Environmental Assessment Reports and Atlases for the West Coast of British Columbia
Environmental Sciences Ltd., Vancouver, B.C. ... 5,000

Identification and Enumeration of Marine Phytoplankton
E.V.S. Consultants Ltd., North Vancouver, B.C. .. 5,978

Benthic Studies in Alice Arm and Hastings Arm, B.C. in Relation to Mine Tailings Dispersal; Part II, Biological Analysis
E.V.S. Consultants Ltd., North Vancouver, B.C. .. 21,361

Size Estimates of Phytoplankton Species
E.V.S. Consultants Ltd., North Vancouver, B.C. 596

Oceanographic Observations Aboard CFAV Endeavour
H. Goldberg, Vancouver, B.C. 1,200

HF SSB Radio System
Harris Corporation, Rochester, N.Y. 14,792

Investigation of Arctic Industrial Offshore Activities and Ocean Dredging and Dumping in B.C. Coastal Waters
R.H. Herlinveaux, North Saanich, B.C. 31,950

Coordination and Publication of a Summary and User's Guide and Brochure for the Arctic Marine Data Compilation and Appraisal Series
Hoot Productions Ltd., Victoria, B.C. 8,600

Development of Computer Programmes for Processing Studies in Ocean and Atmospheric Physics
Interact Computing Services Ltd., Sidney, B.C. .. 21,129

Development of Computer Programme for Analysis of Oceanographic Data from Prince of Wales Strait, Viscount Melville Sound and M'Clure Strait
Interact Computing Services Ltd., Sidney, B.C. .. 40,244

Design of Two Deep-Sea Oceanographic Mooring Systems
T. Juhasz, Victoria, B.C. 5,587

Compilation and Collation of Tsunami Records
M. Lane, Victoria, B.C. 3,045

Horizontal Control Survey for a Planned Hydrographic Survey off the Yukon Coast, West of Hershel Island to the Alaska Border
McElhanney Surveying & Engineering Ltd., Calgary, Alta. 57,360

MSI - H-Series Development
Meyer Systems Ltd., Vancouver, B.C. 120,000

Tsunami Data Computer Programming
M.M. Nugent, Victoria, B.C. 1,980

Analysis of Southern Hemisphere Drifting Buoy Data
Odysseas Ocean Sciences Ltd., Victoria, B.C. 18,850

Analysis of FGGE Drifting Buoy Data
Odysseas Ocean Sciences Ltd., Victoria, B.C. 7,875

Oceanographic Analyses of Sediment and Water Samples from Alice Arm, British Columbia
M. Paryniuk, Victoria, B.C. 26,595

Analysis of Tsunami Potential of Landslides
D. Philip, Victoria, B.C. 5,040

Construction and Testing of Five Floating Ice Pressure Drums
Polar Tech Ltd., North Saanich, B.C. 50,000

Analysis of Marine Air Samples from Weather-ships and Other Cruises
W. Richardson, Victoria, B.C. 6,200

Analysis of Subsea Containment and Free Plume Test
R.D. Rowe, Calgary, Alta. 12,000

Ocean Ecology Research Support to the Institute of Ocean Sciences
S & B Research Ltd., Victoria, B.C. 4,850

Compilation and Interpretation of Marine Meteorology and Precipitation Chemistry Data
S & B Research Ltd., Victoria, B.C. 15,925

Compilation and Interpretation of Marine Meteorology and Precipitation Chemistry Data
S & B Research Ltd., Victoria, B.C. 14,450

Oceanographic Data Collection of the Coastal Waters of British Columbia
S & B Research Ltd., Victoria, B.C. 15,000

Sidescan Development
Sea I Research, Patricia Bay, B.C. 2,800

Analysis of Sediment Trap Material
Seakem Oceanography Ltd., Sidney, B.C. 3,450

A Study of Sediment and Tailings Transport in Alice Arm, B.C.
Seakem Oceanography Ltd., Sidney, B.C. 52,283

Analysis of Extracts of Seawater for Ultra-trace Metals by Mass Spectrometry
Seakem Oceanography Ltd., Sidney, B.C. 10,174

Analysis of Seawater and Marine Air Samples from Weatherships and Other Cruises
Seakem Oceanography Ltd., Sidney, B.C. 71,877

Oceanographic Data and Scientific Analysis Concerning the Canada/Germany Project Flurex '82
Seakem Oceanography Ltd., Sidney, B.C. 28,800

Compilation and Collation of Tsunami Records
P. Straub, Sidney, B.C. 3,995

To Conduct Hydrographic Surveys over Selected Artifiical Island Sites in the Beaufort Sea
Terra Surveys Ltd., Patricia Bay, B.C. 62,813

Survey and Literature Review of the Chemistry of Halocarbons
University of Victoria, Chemistry Department . 7,134

Evaluation of High Resolution Frequency Analysis Techniques Applicable to Doppler Sonar Operations
University of Victoria 1,500

Design, Furnish and Install a Computed Line Steering System
Walker Industrial Computing, Patricia Bay, B.C. .. 9,705

APPENDIX II
Publications

A. Department of Fisheries and Oceans

(1) Canadian Data Report of Hydrography and Ocean Sciences

No. 3	Hill, S., K. Denman, D. Mackas and H. Sefton	*Ocean Ecology Data Report: Coastal Waters off Southwest Vancouver Island.* Spring and Summer 1979
No. 4	Hill, S., K. Denman D. Mackas and H. Sefton	*Ocean Ecology Data Report: Coastal Waters off Southwest Vancouver Island. Spring and Summer 1980*
No. 5 Volume 1	Cornford, A.B., D.D. Lemon, D.B. Fissel, H. Melling, B.D. Smiley, R.H. Herlinveaux and R.W. Macdonald	*Arctic Data Compilation and Appraisal. Beaufort Sea: Physical Oceanography — Temperature, Salinity, Currents and Water Levels*
No. 5 Volume 2	Thomas, D.J., R.W. Macdonald and A.B. Cornford	*Arctic Data Compilation and Appraisal. Beaufort Sea: Chemical Oceanography*

(2) Canadian Technical Report of Hydrography and Ocean Sciences

No. 3	Henry, R.F.	*Automated Programming of Explicit Shallow-Water Models. Part I. Linearized Models with Linear or Quadratic Function*
No. 7	Perkins, R.G. and E.L. Lewis	*Design of CTD Observational Programmes in Relation to Sensor Time Constants and Sampling Frequencies*
No. 8	Ages, A.	*The Development of an Oilspill Tracking Technique*

(3) Canadian Contractor Report of Hydrography and Ocean Sciences

No. 3	Byers, S.C. and G.S. Calderwood (eds.), Dobrocky Seatech Ltd.	*Report on Ocean Dumping R & D Pacific Region Department of Fisheries and Oceans 1980-1981*
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APPENDIX III

Permanent Staff 1982
Institute of Ocean Sciences
A. Department of Fisheries and Oceans

Director-General

Mann, C.R.; B.Sc., M.Sc. (N.Z.), Ph.D. (Brit. Col.), D.Eng. (N.S. Tech.), FRSC

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APPENDIX III

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Mann, C.R.; B.Sc., M.Sc. (N.Z.), Ph.D. (Brit. Col.), D.Eng. (N.S. Tech.), FRSC

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Stevens, I.B.; CIMA (McMaster)
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Korhonen, R.K.
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*Lichtensteiger, P.
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*Schofield, B.
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Taylor, W.R.; Dip. BCIT
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**Woolley, R.; Dip. BCIT
Yee, J.

*Left in 1982
**Joined in 1982
***Educational Leave

Ship Division

Acting Regional Marine Superintendent:

Parkinson, R.W.; Engineer 1st Class Combined; Member, Institute of Marine Engineers

Fitch, L.A.H.; Master H.T.; Assist. Marine Superintendent (Deck)
Smith, F.V.; Depot Supervisor
Craton, M.; Administrative Clerk

CSS *PARIZEAU*

Newton, B.L.; Master F.G., Master
Coombes, A.S.; ON I, 2nd Officer
Loughnane, D.; Watchkeeping Mate, 3rd Officer
*Olcen, P.; Engineer 1st Class Combined, Chief Engineer
Pereira, P.B.; Engineer 1st Class Combined, Chief Engineer
Tran, K.H.; Engineer 2nd Class Motor, Senior Second Engineer
Stanway, J.D.; Engineer 3rd Class Motor, Second Engineer
Palmer, S.; Supply Officer

CSS *VECTOR*

Sjoholm, K.; Master F.G., Master
Wheeler, M.; ON I, 1st Officer
Campbell, J.; Watchkeeping Mate, 2nd Officer
Pearson, R.; Engineer 3rd Class Motor, Chief Engineer
Burrell, R.; Engineer 3rd Class Motor, Second Engineer
McQuarrie, I.; Engineer 4th Class Motor, Third Engineer

PISCES IV

Chambers, F.J.; Chief Pilot
Taylor, R.H.; Pilot
Witcombe, A.; Pilot
Oszust, J.; Pilot
*Thomas, G.; Pilot
Holland, R.R.; Pilot
Shepherd, K.; Pilot

CSS *RICHARDSON*

MacKenzie, R.W.; ON 1, Master

*Left in 1982

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Smiley, B.D.; B.Sc., M.Sc. (Alberta)

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Ocean Chemistry Division

Chief of Division:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip. Mar. Sc. (UNESCO), F.R.S.Chem. (U.K.), F.C.I.C.

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Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)
McLaughlin, F.A.; B.Sc. (Victoria)
**O'Brian, M.C.; B.Sc. (Alberta)
Paton, D.W.; B.Sc. (Brit. Col.)
Smith, G.L.; Dip. NAIT
Soutar, T.J.; Dip. BCIT
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Kimber, P.M.
Kuwahara, L.S.C.; B.Sc. (Brit. Col.)
Lake, R.A.; B.Sc. (Brit. Col.). M.Sc. (Washington)
Lee, A.Y.P.; B.Sc. (Victoria)
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Love, J.
*** McNeill, J.M.
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Melling, H.; B.Sc., M.Sc., Ph.D. (Toronto)
Minkley, B.G.; Dip. BCIT
Miyake, M.; B.S. (EE) (Drexel), M.S., Ph.D. (Washington)
** Moonie, J.A.
Moorehouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra), M.S., Ph.D. (Chicago)
Perkin, R.G.; B.A.Sc., M.Sc. (Brit Col.)
Richards, D.L.
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Ma, A.C.; B.Sc. (Victoria)
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Ocean Ecology Division

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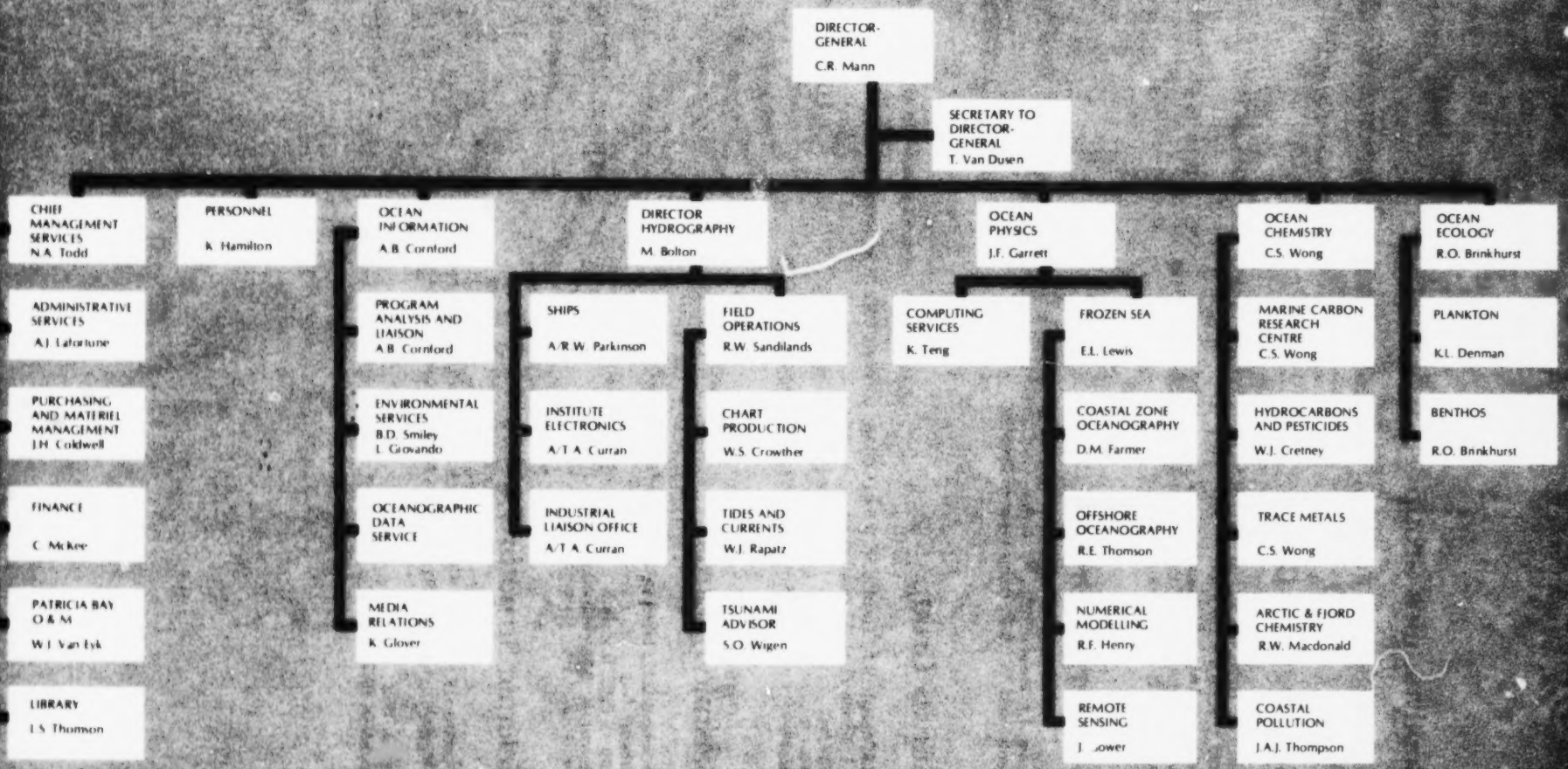
Organization Chart

Department of Fisheries and Oceans



POOR

QUALITY

ORIGINAL